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THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

PROCEEDINGS.

SESSION 1904—1905.

VOL. XX.

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THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

SESSION 1904—1905.

The First Ordinary Meeting of the Session was held at The Institute, Dudley, on Saturday, October 15th, 1904.

THE PRESIDENT (Mr. HARRY B. TOY) presided over a large attendance of members.

The minutes of the Annual Meeting held on the 30th April last, were read, adopted, and signed.

Messrs. A. Birkbeck, E. Blunt, C. E. Bushell, G. K. Chambers, E. B. Crump, D. Davies, H. F. Foster, W. H. B. Hatton, W. Hill, W. King, W. Lindop, R. G. Mercer, W. Moulder, E. Plant, E. J. Raby, C. H. Rathbone, W. Simcns, Stewart S. Siviter, Seth S. Somers, William Timmins, Thomas Turley, and W. Westley, Junior, were elected members of the Institute.

THE VICE-PRESIDENT (Mr. WALTER JONES) here took the chair, and the PRESIDENT delivered the following address:—

ADDRESS BY THE PRESIDENT

(Mr. HARRY B. TOY).

It is possible to obtain from books very useful information upon matters relating to the progress made in the iron and steel trades since its inception in this country, but the detailed reports issued by the Board of Trade (which are reproduced in most of our Engineering Papers), have long since convinced us that our trade generally is declining, and although to some extent the knowledge is depressing, there is no reason why we should be discouraged, if we fully recognise the cause and do all we possibly can to remove it. If the members of this Institute will attend our meetings more regularly and contribute to its useful influence by reading papers, or entering into the discussions, the industries with which we are connected will be very largely benefitted, and the object for which the Institute was inaugurated more fully attained. I propose in this address to point out particularly some of the influences which have so seriously affected our trade and commerce, and if we can properly realise how neglectful we have been in the past, there is no reason why we should not resume that eminent position which this nation enjoyed for so many years.

The possessor of wealth, no matter whether by inheritance or ability, has a great responsibility, as the progress of this and other nations depends very largely upon the proper employment of money. Fortunately for this country, there are many men who have generously subscribed their money to provide Institutes for the benefit of those who are not able to pay for advanced education; they have also provided necessary funds for the establishment of numerous other Institutions, and we are proud to perpetuate the memory of such men, but in my opinion the men who have employed their wealth and time in those branches of industry upon which the labouring portion of our community have to depend for their existence, are the men whose names should appear most prominently in the history recording the progress of our empire.

All the members who had the privilege afforded to them by Professor Turner of inspecting the Birmingham University were, I am sure, delighted to find what elaborate means are being provided for the thorough technical training of our young men, and I sincerely hope they will make the very best use of their opportunities, but the good intentions of the promoters will not be fully realised unless means are

forthcoming for the further development of the knowledge obtained thereby. It is a deplorable fact that many of our most prominent and skilful young men are at present employed abroad, and are using their knowledge for the benefit of our foreign competitors.

Many of us could mention numerous instances where sons of iron-masters have received a collegiate education, but in consequence of not having been afforded an opportunity of spending the capital to provide modifications necessary for even the continuance of an old-established business, the same has become extinct, and their knowledge has been of no avail. When I was travelling through Germany last autumn, and saw so many of my own countrymen, just in the prime of life, occupying important positions in iron and steel works there, the question arose in my mind, Are these men here because the advantages of education are superior in Germany to those in England? but I soon concluded that the real reason was that the German capitalists had a keener conception of a man's ability, as they had in the employment of the wonderful inventions of Bessemer and Siemens. I respectfully suggest that if the modifications at present so much needed in our works were entrusted to the skilful men employed in them, the thought of engaging Americans and Germans would never have been entertained.

I do not at all agree with the prevailing notion that competition is due to the influence of bad trade, for in my opinion, notwithstanding the fact that it seriously affects individuals, it is the main source of national progression.

There are two sections of our community which do but little towards the welfare of their country; the one is, those who concentrate the whole of their mind to the purpose only of making money, and the other those who invest their wealth in gilt-edged securities, and live an unproductive and useless life. If only these two sections could realise their responsibility the trade and country generally would derive some benefit.

All the members of this Institute who went to Scotland and had the opportunlty of visiting most of the ironworks and steelworks in and around Glasgow, were astonished to find, not only how far South Staffordshire was behind the times, but what a hearty welcome was accorded to them by the proprietors and staff, and the liberality with which our members were supplied with valuable information was an object lesson to all of us in the Midlands. There appears to me an idea prevailing, that the only way to success is by hiding from all competitors secret methods of manufacture, but in my experience in the majority of such cases, the adherence to these methods has tended more in the direction of closing works than most users imagine, and I fully believe that the sooner we realise the advantage of exchanging views with our more advanced competitors, the sooner we shall derive

benefit ourselves, and enhance the value of the Midland industries generally.

I come now to the bad influence of the railway companies on the trade of our country, and although I do not ignore the reasonable demands of the shareholders, I think every trader will agree with me that some reform in railway rates is absolutely necessary, if their own and traders' interests are to be maintained, for we hear almost constantly of works being closed, and others being removed to the coast, as the result of unreasonable railway rates.

We all, I feel sure, realise that the construction of railways costs very much more in this than other countries which are more favourably situated, but we have a right to inquire why it is so, and I think if a Commission were appointed to investigate the facts, and report to the country the actual state of affairs, that pressure would very soon be brought to bear in the direction of reduced rates. The unfair advantages which our railway companies offer to our foreign competitors tend more to the creation of unfair competition than is generally known, and if only the rates charged for imported goods from shipping ports, were brought clearly before the British public, some sort of reform would, I feel sure, be demanded. In several instances the cost of sea freight and railway carriage charged for foreign goods delivered into the Midland counties, is even less than our railway companies charge Midland traders to carry similar goods to English sea-ports, and until these conditions are altered the progression of this country will be greatly impeded. This question will necessarily have to be faced, otherwise I cannot see how the industries in our Midland counties are likely to survive. The railway companies here have, no doubt, temporarily strengthened their position by amalgamating with the canal companies; but such a policy will increase the difficulties in developing other industries, and ultimately their own interest must necessarily suffer. It would be most valuable if an uninterested Member of Parliament would institute an inquiry into the question, and so induce the railway companies to give to the traders of Great Britain every advantage possible.

When making comparisons between this and other countries, the question of railway rates should receive due consideration, and the following facts may be of some interest. In Germany the carriage of goods costs in many instances only about half what is charged in this country. This fact also applies to Belgium; and the difference in their charges for passenger traffic is even greater. With a five days' third-class ticket, which costs 9s. 3d., a passenger is entitled to travel over the whole, or any portion, of the railways thoughout Belgium, and for the conveyance of a bicycle an extra charge of only 7d. per day is made.

The State-controlled canals of Belgium also contribute very largely

to the advantage of the commercial and industrial enterprises of their nation, and the following figures will illustrate the consideration which is there given to inland navigation. The total length of their waterways is 1,360 miles, the total area of the country being 11,373 square miles; there is thus one mile of waterway to every $8\frac{1}{3}$ square miles of territory. The importance which the State attaches to the utility of the canals, may be estimated by the fact that 85 per cent. of these waterways are under its control, and it is a large shareholder in the remaining portion controlled by private companies. Their canal system is intended to serve as an auxiliary to the railways, which also are controlled by the State, and by a policy of low freights inland industries have been considerably developed. During the last twenty-five years the State has spent about £16,000,000 in the development of the canals. It is very easy, I think, to recognise what a benefit would accrue from a similar policy, if goods could be conveyed from the Midland counties abroad without transhipment as in their case, and yet we go on, year in, year out, perpetuating worn out and costly methods, and as old-established businesses are being demolished, the railway and canal companies compensate themselves for the loss of traffic by increasing the rates and tolls to the few remaining traders. Gentlemen, I think you must all agree that in the interest of traders and shareholders alike the time has arrived when these details should be thoroughly investigated and adjusted, otherwise our opportunities of competing satisfactorily with our foreign friends will be lost for ever.

The next point for our consideration is quite as important in our endeavour to maintain a fair share of the trade of the world, and that is the consumption of coal. Coal in other countries is recognised as national wealth, and used as such, and the more we imitate them in this direction I feel sure our position will be materially strengthened. It is very much to be regretted that in a single month we export no less than 4,000,000 tons of our coal, and I am sorry to say much of it at lower prices than are charged to our own manufacturers. This, to my mind, is absolutely wrong, and another reason why our trade is declining. Does this not provide for our foreign competitors one of the most important necessities of almost every industry with which they are connected, and does it not afford them a splendid opportunity of beating us with the rod with which we supply them? In many instances articles are manufactured abroad by the use of our own coal, and sent into even our home markets. This is also a deplorable fact, and the sooner a tax is imposed sufficiently high to prevent such a suicidal policy the better for this country.

Need we be surprised at strikes and labour troubles when such facts are revealed, and yet how very little interest is taken in this matter by the authorities who are in a position, by Act of Parliament or otherwise, to influence some beneficial change.

One has only to look at the volumes of smoke emitted from the chimneys of our large works to recognise what opportunities yet remain for economy in this direction. We are conscious that there are so many units of heat and power in every pound of coal we use, and although we realise what enormous waste is taking place, methods of economy are extremely rare. Why have we not interested ourselves in this most important question before? There can be but one answer, and that is because we have not been compelled by force of competition; however, we are now awakening to the necessity, and although the task is now difficult in consequence of gross neglect, there is no doubt that great economy will be effected in the use of coal in the future, and all of you who have had the advantage of seeing the numerous gas producing plants at present in course of construction, providing cheaper motive power, will agree, I think, that in the near future we shall be in a more favourable position to combat the competition of our more enterprising neighbours. Those of you who have had occasion to compare the costs of producing power by gaseous fuel and gas engines, as compared with boilers and steam engines, will be very much encouraged by the possibilities of economy which will no doubt tend to the development of nearly every trade and an increase in the demand for labour.

Touching now upon the question of labour, there are many considerations involved, and having seen the conditions of working men in Germany, Belgium, and Austria, and with a full knowledge of the poverty existing at present among our labouring men, I am convinced that under normal conditions the British workmen are in a more favourable position as regards wages and hours of labour. There is, however, one advantage which the foreigner possesses, and that is that he can procure a refreshing and wholesome glass of beer at a reasonable price, without experiencing the disgraceful influence which follows the use of what is called beer in this country. During the whole of my journey abroad I never saw a drunken man. I know that the introduction of any measure which will influence a reduction in brewery profits will meet with great opposition, and our only hope is that the working classes will ultimately be educated to realise the actual value of this obnoxious beverage, as they do tea and coffee; the desired effect will then be assured I would not refuse workmen a glass of beer at the proper time; on the contrary I would give perfect freedom to every man as to the quantity he drank, and if I could control the matter would see that the cost was very much less than at present and the quality superior. There are many difficulties in dealing with the workmen of this generation, but I am quite sure that as the influence of education extends, these troubles will be very much reduced. They will never, even by this means, be entirely removed. It is possible, however, for employers to use some good influence which will not only enhance the value of their employees, but will also develop the men's higher nature. There are employers, unfortunately, whose workpeople

have to sit and take their meals in filthy and dirty surroundings, and their opportunities of healthy recreation are extremely limited. We cannot wonder, then, that these men do not work satisfactorily or with intelligence. If employers would pay a little more attention to these details, the homes and lives of their workmen would be brightened, and the troubles between labour and capital considerably reduced. I could mention many instances where employers have improved their own position and that of their employees by providing a comfortable room for meals, hot water and gas for cooking, science classes, lectures. and numerous recreations, and the businesses have been conducted profitably and without the many difficulties often experienced by less prosperous employers.

The question of Protection is at present being very much discussed. Without wishing to enter into a political controversy, I feel justified in expressing here my views upon this very important matter. Reasonable arguments may be advanced in favour and against; but I have a strong conviction that a sudden reversal of a policy under which in the past this nation has maintained such a supreme position will be attended with very great danger. That we are suffering from the effects of foreign competition no one can deny, but is not the real cause attributable more particularly to our adherence to the methods of manufacture inaugurated by a former generation, and if so, why not adopt. first of all a policy of reducing our costs of production by the employment of more modern machinery? Protection in any trade provides temporary profits for all the few firms concerned, but from a national point of view it is the greatest possible hindrance to progression, and the more we restrict the importation of foreign goods, the more will our prices be increased to the detriment of the consumer, and the intention to reduce costs of production will diminish in the same ratio. Combinations and Protection are benefical, no doubt, to a manufacturer who has not advanced with the times, and will benefit the one who has to even a greater extent, so long as it lasts. Our neighbours are adopting a more rational course, and offering to our customers abroad cheaper articles, and our only chance is to drop all influences of inflated prices and enter into the race of progression.

The most successful firms in the future, as in the past, will be those who employ a share of their profits in improving their plant. They can not only supply the consumer at a low price, but are in a better position to compete successfully with our foreign friends, and increase their employment of labour.

The question is asked, why do countries where Protection is adopted prosper to a greater extent than those which allow free importation? This fact did not apply until recent years, and it is not now due so much to the influence of Protection, as to the development of their canals, railways, and the adoption of the most up-to-date methods generally.

Pay a visit to our collieries, steel and iron works, and see the old-fashioned egg-ended boilers, and worn out Beam engines grinding away; see also how little is yet realised of the importance of using steam expansively, and condensing, and then pay a visit to the successful countries and see the conditions comparatively, and in my opinion you will no longer allow Protection to absorb your mind. Protection will not increase demand. It will not reduce the cost of production. Protection will not allow us to close our doors to foreigners, and by some magic means open the doors of all foreign countries to our goods at high prices and to the detriment of the consumers, even in our own Colonies. These are not questions which one legislator may decide. It is a question for the nations concerned. It appears to me quite unnatural for all our Colonies to neglect their own interests for the benefit of the Mother Country; no matter how favourably they may be disposed towards her, they will not pay high prices influenced by unnecessary high cost of production.

We do not hear what proposals are forthcoming with regard to pig iron and other materials which our Colonies are dumping here, neither do we hear very much objection to the principle of dumping as between England, Scotland, Ireland and Wales, therefore the principle seems admissable even here, so long as the influence is in the right direction.

In my opinion our industries are needing a little reasonable aid from the State in the direction of reduced railway and canal rates and cheaper coal. There are instances when a reduction of ½d. per ton on coal in some of our large steel works would provide a 5 per cent. dividend to its shareholders. What an influence, therefore, would this one detail only exert!

I think also the State should provide some inexpensive means of settling trade disputes, for it appears to me there is some reform in this direction needed, seeing there are many instances where a plaintiff in our law courts may obtain judgment with costs, and yet be out of pocket almost to a greater extent than the amount of the debt he seeks to recover.

I should like for you to consider for a moment, an instance of the practical result in an adaptation of the methods suggested for the preservation of our industries. You will all remember how seriously the American McKinley Tariff affected the tin plate trade of South Wales; in fact nearly the whole of the works were closed in consequence; but the ultimate influence was a good one, for the proprietors were compelled to modernise their methods by the adoption of water tube boilers, compound condensing engines, larger rolls, stronger housings, electrical installations, and numerous other economies; and to illustrate the position of to-day I will give you an abstract from the *Labour Gazette*, for September:—

TINPLATE WORKS.

An improvement is shown in the tinplate industry, as compared with both a month ago and a year ago.

At the end of August 379 mills were working, as compared with 354 at the end of July, and 345 a year ago. At the 75 works open, 58 had all their mills in operation, while the remaining 17 works had 77 mills going out of a total of 109. The estimated number of workpeople employed at the 379 mills was 19,000

In the South Wales, Monmouthshire, and Gloucestershire district 369 mills were in operation at. the end of August as compared with 342 a month ago. and 333 a year ago.

The following table shows the number of mills at the works which were giving employment, full or partial,* at each of the three periods :—

	No. of Works open.	No. of Mills in such Works.		
		Working.	Not Working.	Total.
Works giving full employment	58	302	...	302
Works giving partial employment ...	17	77	32	109
Total at end of August, 1904* ...	75	379	32	411
*Corresponding Total for July, 1904**	75	354	53	407
Corresponding Total for August, 1903†	66	345	40	385

The *Exports* of tinplates and blackplates from the United Kingdom in the months covered by the above Table are summarised below :—

	Tinned Plates & Tinned Sheets (Iron or Steel).			Black Plates for Tinning (Iron or Steel).		
	Aug., 1904.	July, 1904.	Aug., 1903.	Aug., 1904.	July, 1904.	Aug., 1903.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
To United States ...	6,913	7,007	3,587	13	—	71
„ other Countries ...	25,685	17,986	16,881	4,964	3,942	5,022
Total ...	32,598	24,993	20,468	4,977	3,942	5,093

* It will be understood that, in addition to the works returned as giving full or partial employment, a certain number of tinplate works were wholly idle at each of the dates to which the returns relate.

† Revised figures.

This result, at a time when trade is very bad, is most encouraging, and if it applies in this important branch of business, it is quite certain to apply in others. The most enterprising men in this country now fully recognise the real influence of our trade difficulty, and all those who are deeply interested in the real welfare of this nation must be proud to see what means are at present being provided for reducing costs of production, as this is the detail to which we must look for the way out of our difficulty.

This district has benefitted by the enterprise of Sir Alfred Hickman and The Earl of Dudley to a very great extent; and it is very evident from the enormous amount of money they have recently spent, and are to-day spending, that they attach very great importance to the necessity of keeping abreast of the times, as a means of maintaining our trade.

I mentioned in a paper I read before you some years ago that attempts were being made in Staffordshire to roll steel sheets in old mills previously used for rolling iron sheets, and that I thought this would not be done successfully, and I am sorry to say that to a great extent this has now been proved, very much to the detriment of this district. The reason is not difficult to see, as the sheet trade has undergone a very great change, and even associations will not maintain an industry for ever.

We hear that it is impossible to make steel sheets profitably in the Midlands, and although I am not an expert in this business, I feel quite sure that this assertion is made without regard to the more modern methods which they have never tried. A very large amount of work necessary in the production of steel sheets is now performed in grooved rolls. In fact, the bar is comparatively a thick sheet before it is treated in the sheet mill. The mills are also more massively designed than formerly, to allow a more rapid reduction in the thickness, even at a lower temperature. The mills are also being driven by compound condensing engines, gas engines, and even electrically. Another saving in the cost of production, is the eight hours "shifts."

The iron sheet trade of Staffordshire was surrendered long before the most economical methods of production were tried, and it seems a great pity, as the corrosion in steel sheets is so rapid that I feel sure there will always be a demand for best iron sheets.

During the last few years new bar iron works have been erected in Scotland, whilst the trade in this locality is gradually diminishing. The reason given, of course, is that our Scotch friends have the advantage of being on the coast. This is true; but can we produce in our mills the same quantity in the same time of even an equal quality; are our furnaces of the same capacity, and worked as economically; do we absorb the same quantity of heat from our furnaces, and distribute the power where required; do we reduce the percentage of scrap by rolling large diameter and longer rounds by guide? The answer to most of

the questions is no. I know some will continue to say that this can only be done at the expense of quality, to whom I reply that if the quality is not suitable for the purpose, it is a detail which very soon asserts itself as a matter of business.

A method which in our steel mills we seem slow to adopt is rolling all sections possible in three high mills There are difficulties in adjustments of the rolls, but these may be overcome, and I think we may look forward to these mills taking the place of the costly reversing mills for rolling steel sections. In my opinion, the power required for driving these mills will be generated by gas engines and transmitted electrically, as is being done in Germany, and an estimate of the cost of providing the necessary power in this way will convince anyone that the method is bound to be adopted.

The elaboration of German rolling mills is considered to be an expensive luxury here, but if our mill rollers had received a better mechanical training, very many of these so-called luxuries may be used to very great advantage in the production of perfect sections at reduced cost.

It appears to me that the correct method to employ in our steel works is the continuous one; that is to say, the raw materials should be charged into the blast furnace mechanically, and from the time the metal is reduced to a molten state it should be conveyed to a mixer, then to a tilting furnace, and the ingots should not be allowed to lose any initial heat until the desired section is finished. This method is being adopted in several of our steel works now, but some of the arrangements for charging the ingots into the furnaces, and conveying them to the mills, are too slow, and this neglect is attended with very serious results in the way of breakage of machinery and other details.

I have been associated for a great number of years with designing and manufacturing rolling mills and machinery employed in steel and iron works, both in this country and abroad, and I can say without hesitation that there is also in this industry a good opportunity of reducing costs of production. This question, however, is now receiving very careful consideration by some of the enterprising men connected with the trade, and I hope that by the time our ironmasters decide to employ more modern machinery they will be able to procure it locally.

A paper was read some time ago upon the breakage of chilled rolls, and if it had the influence of reducing the quantity it served a good purpose, but we have not yet reached that state of perfection that every maker and user is striving to attain. Being intimately acquainted with the details of the manufacture of chilled rolls, and also the many purposes for which they are used, I recognise that very great care is necessary in the production, as in the use, of them; but considering the scarcity of the raw material with which they are made, and the enormous increase in output of the mills in which chilled rolls are employed, it is

encouraging that we have, so far, been able to meet the demand for an improvement in quality. It is, of course, quite impossible for the costs of chilled rolls per ton of plates and sheets in all works to agree exactly, as the methods of using them, even for the same purpose, vary considerably; but I could mention instances of sheet works employing six or eight mills where not a single roll has been broken during a whole year. I do not pretend that this is entirely due to the quality of the rolls, as the skill of managers in using mills most suitable for their various orders is a detail quite as important in attaining such a result as the roll itself, and equally important is the employment of skilful rollers and turners. The prices charged for chilled plate rolls now constitute a very small proportion of the total cost of producing a ton of steel or iron plates, calculated by the figures that in many instances 90,000 tons of plates have occasionally been produced in a single pair of rolls. Notwithstanding these facts, I am convinced that ultimately more careful attention to the chemical and physical changes which take place in the smelting of ores for this very delicate branch of business, and by more careful manipulation of the pig iron and other modifications very admissable, there is a probability of a further development. The demands, also, for grain rolls used in producing steel sections have altered, as the increased outputs of these mills necessitate much harder rolls; but makers, although there are difficulties in providing hardness without risk of breakage, have succeeded satisfactorily, and it is hoped that as Staffordshire all-mine pig iron is so eminently suitable in this development, that this branch of trade may further develop.

Well, gentlemen, I thank you for so patiently listening to my few remarks, and although there are several views I have expressed with which you may not agree, I hope I have strengthened your conviction that, to some extent, we in Staffordshire can influence some change which our nation needs in maintaining a fair share of the trades which are necessary for our existence.

There is an old patriotic song, "We've got the ships, we've got the "men, we've got the money, too," and the only thing for us now to do is to send to Parliament sound business men, whose interest is our interest, and who are in the best possible position to know how to use our wealth to the best advantage. The grand old country will then be destined for a longer life of prosperity.

THE DISCUSSION.

THE CHAIRMAN: I think you will agree with me that our President has given us something to think over, and if you discuss this address as it deserves, you will be here all night. He has raised some very important points, and on some of them, as he states, we should perhaps not all agree. At any rate we are indebted to him for a very excellent

address. I wish to propose that the best thanks of this meeting be given to Mr. Toy for his paper, and I hope that whilst discussing it you will try to avoid, as far as possible, the political matters. Personally I agree with a great deal of what the President says, but it matters very little what my own personal opinion is, though I presume we are all anxious to do what is best for the country at large. There are one or two points I would like to refer to. On page 2 he says:—"In my opinion the men who have employed their wealth and time in those branches of industry upon which the labouring portion of our community have to depend for their existence, are the men whose names should appear most prominently in the history recording the progress of our Empire." Most of us are aware that it is usual to put up monuments to people who go and kill each other. Why can we not put up monuments to men whose efforts tend in the direction of peace instead of war? I have often been struck with that idea, and therefore I am very pleased to find our President expressing himself in that direction in the way he has done. On page 3 he says:—"There are two sections of our community which do but little towards the welfare of their country; the one is, those who concentrate the whole of their mind to the purpose only of making money, and the other those who invest their wealth in gilt-edged securities, and live an unproductive and useless life." This is very true. There are a good many men, I am afraid, at the present time, who are trying to get something for nothing, and there is a good deal of speculation not only in business but in other matters. In fact, it has become quite a business, this trying to get something for nothing, and I think his remarks are very much to the point on that matter. On page 4 he refers to "The bad influence of the railway companies on the trade of our country." He considers that some reform in railway rates is absolutely necessary, and I think we shall all agree with him. The railway companies, besides charging low rates upon foreign goods, have lately introduced a great many very harassing restrictions. In sending out consignments in my own business they will divide them up into two or three sections, and charge, say, boilers, pipes, and india-rubber rings, at various rates. With regard to india-rubber rings, in some cases, although it is impossible to damage them, the charge comes to 90 per cent. of the cost of the goods. I have had a good deal of trouble with these trumpery, harassing restrictions which a great railway company ought to be above introducing. Then again, foreign goods are brought some thousands of miles by water, and 200 or 300 miles by rail cheaper than you can consign them from the Midlands to a seaport. His other remarks as to railway rates are quite correct, and I have had several instances of them in my own experience. On page 5, speaking of Belgium, he says their canal system is intended to serve as an auxiliary to the railways, which also are controlled by the State, and by a policy of low freights, inland industries have been considerably developed. So long as the railways in England belong to

companies I suppose high railway rates will continue and we shall have "to grin and bear it;" unless traders can bring some considerable influence to bear upon the companies, and unless you can show them that it is to their own interests to make the rates reasonable. At the bottom of page 5 he calls attention to the fact that in many instances articles are manufactured abroad by the use of our own coal, and sent into even our own home markets. "This is also a deplorable fact," he says, "and the sooner a tax is imposed sufficiently high to prevent such a suicidal policy, the better for this country." Well, I daresay you remember how some of the colliery proprietors in South Wales protested against the tax of 1s. per ton. I think if a tax of 5s. per ton had been put on it would not have been too much. You cannot replace the coal which is taken out of this country, and I think it a very reasonable thing for the Government to put a tax on that coal which is sent from Great Britain to France or Spain or Germany, or any other country. If the coalowners like to protest, let them go on protesting. It seems to me a reasonable source of revenue. On page 6 he refers to the introduction of gas power, and considers that with cheaper motive power the manufacturers of the inland districts will be in a more favourable position to combat the competition of our more enterprising neighbours. There is a very great deal in what he says. I had a table sent me lately showing that a gas plant drove an engine at 1-26th of a penny per indicated horse-power per hour, which is a very low price compared with any steam plant I have ever come across. He further says:— "There are employers, unfortunately, whose workpeople have to sit and take their meals in filthy and dirty surroundings, and their opportunities of healthy recreation are extremely limited. We cannot wonder, then, that these men do not work satisfactorily or with intelligence." Sometimes the men do not care for these comforts. I was one of those employers who unfortunately put up a dining room for the men, with pictures and papers and a cooking range, but I could not get the men to go into it. They preferred to sit on the sand, or by the fires although it was nearly suffocating. So that, eventually, the room was taken down. None the less, I agree with what the President says, and I think that such arrangements should be insisted upon. I asked the men if I should provide lavatories so that they could have a wash after work and go home to their wives and families clean; but they laughed at the idea. The fact is, they want educating up to it. There is no doubt a great deal in the author's idea that a good many manufacturers are working on the old-fashioned lines of 30 or 40 years ago in many ways. With regard to Protection, that is dangerous ground and I won't tread on it. The author says, on page 8, that he thinks the State should provide some inexpensive means for settling trade disputes, and it appears to him there is some reform needed in that direction, seeing that there are many instances where a plaintiff in our law courts may obtain judgment with costs, and yet be out of pocket almost to a greater extent

than the amount of the debt he seeks to recover. Well, all I can say is, "Don't look to the State for that." The Government have a great deal more to do now than they can accomplish. You must not expect the State to look after affairs of trade and commerce unless you yourselves send men to Parliament who will insist upon it. Parliament has promised Old Age Pensions for a good many years, but these have not yet been established. The fact is, you must insist upon reforms before you get them. Again, on page 10, with regard to the possibility of making steel sheets profitably in the Midlands. A gentleman called on me last week and asked for the name of a good house in Staffordshire for iron boiler plates about $\frac{3}{8}$in. or $\frac{7}{16}$in. thick. He said his people were dropping steel plates for iron, and I should think there is a splendid opening for a good iron plate mill in the Staffordshire district. With these remarks I propose a hearty vote of thanks to the President.

Mr. WALTER SOMERS: I have pleasure in seconding the vote of thanks, but I certainly cannot agree with all the views expressed in the paper. With regard to the Coal Tax for instance, I would ask our President how he would like to have to pay a tax on every chilled roll which he sent out of his works to a foreign country, whilst the foreigners are allowed to send rolls here free of tax. British manufacturers in several industries have to face a good deal of unfair foreign competition. In some cases foreign governments give a bounty of 10 per cent. on iron goods sent across to this country, and in many of these instances the makers have previously obtained the necessary pig iron from this country and we have paid a duty to the foreigners before they would receive it. When the manufacturers on the other side melt that pig up, they report to their Government that it is for making rolls, or whatever it may be, to come back to England. The Government officials then visit the works and mark the iron, and the duty is allowed to the ironfounders as an allowance, that is whatever duty has been charged; so that, supposing the pig iron was £5 per ton and there had been 20 per cent. duty put upon it, the buyer abroad would have 20 per cent. returned to him by his Government and he would also have a considerable bounty for sending the chilled rolls or other castings into this country. Now I don't think all the machinery in the world would help that; still I am not going to find fault with that part of the President's address for the simple reason that when customers order more big chilled rolls from him, they will want more big shafts from me. I can supply such shafts up to 30 or 40 tons each in weight, so I am quite sure we shall turn out a great deal more material by having modern machinery.

Mr. SOMERS, continuing, said: I know in a particular case, well, it was my own case, that I was driven out of the market by foreign competition. The German forge received a 10 per cent. bounty upon the material coming to this country, and although there was a great deal of railway carriage on the other side, the sea freight, and again as much land carriage in this country, the goods came from the centre of

Germany to the Midlands here for less money than my carriage was from my works to Leeds. Now I cannot agree with the President that machinery is going to rectify those things, and I am not going to say that Protection is quite right in the way some people put it, but I do say that whatever they mete out to us we should mete it out to them in return. You might say, "What can we do with 10 per cent.?" Well, a great deal could be done with it. The system followed by Protectionist countries with regard to duties and bounties is like having a big bag. Into that bag go the duties we pay, and out of that same bag come the bounties they give to our competitors abroad for sending goods here; so that we indirectly supply the bounty money to our foreign competitors. And now I have nearly done with the subject of Protection, but I should have liked an argument with the author, because I am quite sure he is wrong, though I daresay he equally thinks that I am wrong. I want to know why the foreigner should receive a bounty for sending goods into this country and yet charge a tariff on goods which we send to them. Now as to sheets—we are able to compete with other countries in the markets of the world in galvanised corrugated sheets because we buy the foreign blooms, and in that way we get cheap material for rolling the sheets. The working men of this country will sooner or later awaken to the fact that in making the blooms in foreign countries, instead of in England, a great deal of their labour is being taken from them, and they will sooner or later put that right. The working men will get very tired of it. I think such fine steel works as we have round here. such as those of Sir Alfred Hickman Ltd. and the Earl of Dudley, could make blooms pretty nearly as cheaply as the foreigners can. But whatever our English steel makers may do in the way of saving by taking the metal direct from the furnace, or by other processes, and whatever machinery they may put down, they will not be able to overget the bounty which is given to the foreign steel makers who send their blooms over here.

Now as to economy in the use of coal. It is sometimes said that we are very wasteful of coal in Staffordshire, and that the immense quantity of smoke from our chimneys shows a great waste of fuel. We have improved very much, and I don't know that other districts are much better. On our recent visit to Scotland, we expected to see great improvements in the way of smoke consumption in the furnaces, but I was not quite so enamoured of some of the places in Scotland as I had expected to be. Talk about our living in the Black Country! why, we saw districts quite as black in Scotland. We know there is waste when we see volumes of smoke coming out of the stacks instead of its being consumed in the furnaces. There is more than one place in South Staffordshire working far more economically than works in Scotland. I am not finding fault with the Scotch works. They were all very generous to us, and some of the establishments worked very economically; but I expressed the same opinion to our friends who were showing us round. I told them they were certainly not perfect with regard to smoke consumption

The President has spoken of railways. I quite agree with what he has said about the need of lower rates; and as to waterways, you have known my views for years past. These waterways should be cut right through England. You may remember that there have been several attempts to improve the water communication between the Midlands and the coasts, and some of us worked very hard at one time in that good cause, and although we were not successful, I think the matter is not ended, but merely postponed. The railway rates need to be brought down to a proper level for the sake of the trade of this country, and in order to obtain this, there must be a waterway through to London.

As to coal and Protection, is the President going to protect the South Wales colliery owners? If a coal tax is going to be placed upon coal, the Welsh coal-owners might say—"That is my coal; I can send it where I like; no one has anything to do with my coal." Mind, I don't agree with it going out of the country. But, you know, you must carry these ideas right through, and if you are going to put a tax on exports in one trade you must also put them on in another. You must not legislate to suit your own particular industry and no other. You must be fair all round. If you are going to put a tariff on the things going out of this country and charge the foreigners with that, then you must charge the foreigners a bit also for bringing things into this country. Let us have it the same all along the line. I know what time and thought it takes to write an address like this, and I am sure we are very much indebted to the President for the very instructive paper he has read to us to-night. We shall have an opportunity for discussion and for picking out certain points which we like or dislike, as the case may be, but howerer that may be, we shall give him credit for having devoted great attention to his subject, and for having giving us a paper which is very interesting to us and a great credit to him.

MR. L. D. THOMAS: Will you allow me to say one word? Professor Turner said recently that we cannot get enough supplies of steel and manufactured goods in this country. The country does not produce enough to supply itself. He said, "We have ordered those girders for some of the new University buildings for three months, and there is no sign of them. If we had ordered them from Germany or Belgium they would have been here and in their place." It seems there are large sections which are not made in this country, and consumers have sometimes to go to the other side of the water to get them. What would become of us if they could not make them? Protection or no Protection we are obliged to obtain them somehow. We must get our machinery brought up to the modern standard so that we can produce everything wanted, and produce it in larger quantities, and then there will be no need to go abroad for it. If you put powerful machinery down and produce goods in larger quantities than at present, and at less cost, then we need not go abroad; and until our country awakes to that fact it is done. Mr. Jones said he should like to see the 1s. tax on coal trebled.

What would be the result? The papers say that the coal owners are losing money now, because that 1s. per ton tax on coal has enabled France to send coal into markets which we were previously supplying.

MR. PARRY congratulated the President on the able address he had delivered, and expressed the hope that the members of the Institute would adhere to the rule which had worked so well in the past, viz., to avoid any subject which was likely to give rise to a political discussion.

Mr. W. H. VENABLES: I should like to express my admiration and appreciation of the paper. I think its excellence lies in the fact that it is not one viewed, but is many sided in its outlook upon the subject. We know that the men who make mistakes are the men who take one line and one outlook, but our President, like a wise man, has viewed the whole field of the questions relative to the trade of South Staffordshire, and upon that he is to be congratulated. I take it that his reference to this much discussed question of Protection (which certainly does divide men) need not be objected to. I, for one, do not blame him for that because I recognise that he has merely, so to speak, touched the fringe of the subject. I am not a manufacturer, but I am interested in the welfare of South Staaffordshire, and am one of those who believe that South Staffordshire is not worked out. It contains men of ability and experience, and if they will only throw away some of their prejudices and look at things from a reasonable standpoint, and take broad views of things, as our President has done, they will no doubt be in a better position and deal with matters more profitably than they can do now. There are several points in the address which are very interesting to anyone who reflects upon the relations between employers and employed. Take, for instance, the provision of an eating house. What are the relations usually between employers and employed on that point? I am afraid that many employers allow their men to provide for and shift for themselves in this respect, and are content mostly to have men working for them without giving them another thought, and when after the day's work they drive off to their own dinners, they forget all about the men. Only few of the masters interest themselves in the men's general welfare. I think is this a question which should receive the attention of manufacturers. I have very much pleasure in expressing my sincere appreciation and admiration of the paper.

MR. JAMES RAYBOULD: There is a certain manufacturer of heavy hinges in the Wolverhampton district whose goods have been sent from the Midlands to London for 20 years at the 15s. rate, collected and delivered. Another article which costs about the same in production is manufactured by the same firm and still goes at that rate. But during the last fifteen months the railway company have insisted that these goods belong to another class, and they are to-day charging 24s 2d. per ton for them. There is no difference in the value of the material

from which they are made, and there is practically no difference in the cost of labour, and yet one is charged at the rate of 9s. 2d. per ton more than the other, although the value of the finished articles upon which the 24s. 2d. rate is charged is £3 per ton less than those carried at 15s. per ton. As a consequence that trade is doomed, as far as South Staffordshire is concerned. The bars out of which those goods are made will go as bars to other districts, and will be manufactured into hinges, thus robbing South Staffordshire of that industry. Those articles have been the subject of litigation in Birmingham, and prosecutions are also threatened in Wolverhampton, because the makers have several times consigned those goods under a different class to that to which the railway company say they belong. That is a sample of the injustice which is being done to-day by the railway companies. Our President referred also to the working men in our country being better situated than in other countries. One point which to my mind was rather amusing—and I fail to see how it bears on the interests of our working men—is the remark that they are able to get a better glass of beer at a lower price. The effect of the traffic in question upon our trade is more serious than we are apt to consider. If we could work out the cost of the traffic upon our manufactures we should find that, directly or indirectly. it was 10 per cent., or even a greater charge than that, upon our cost of production. The neglect of work, the unfitness of some men to do their work when they do come, and the rates and charges imposed by local authorities—all these are so many burdens upon our industries which makes trading a very serious matter. This drink question interferes with the steadiness and reliability of the workpeople, and in that way it is paralysing the efforts made by our most skilful managers to keep down the costs of production. Our friend Mr. Somers spoke about bounty-fed goods and how they were affecting us Our friend across the sea—Canada—is already giving a bounty on pig iron produced from native ore, also on steel made from Canadian pigs. And Canada, by-and-by, will not only be making enough of these materials for her own wants, but will have sufficient over for export, and will be offering them to us and to our markets. And then how shall we compete? Germany is in much the same way. It is known that five or six sites have been secured in and about Birmingham in readiness for the time when we adopt Protection (although they are not as much enamoured of the prospects now as some little time ago), so that if German goods are prevented from coming into this country by a tariff, then German workpeople will be brought here to manufacture goods in this country, and those goods will be produced with German labour at 65 per cent. of the amount paid for English labour. What then shall we do?

Mr. G. K. CHAMBERS: I should like to thank you for your paper, Mr. President. On page 11 you refer to the question of continuous rolling, which you advocate. Some figures I have seen lately are rather suprising. The mill I have in mind was fed by live rolls, driven

electrically. One of the advantages of electric driving is that it is possible to take very accurate measurements of the power absorbed in various portions of the mill. In this particular case the power absorbed in overcoming the inertia of the live rolls only, due to the constant reversals, was 80 per cent. of the whole power which was going into those rolls, so that the useful work was only 20 per cent. of the whole power absorbed. That goes to show that continuous rolling should effect great economies. On page 5 you refer to the economy of coal. I always think we in England are in the position of the spendthrift who is living on his capital. Coal is very largely the capital of the country, and I decline to accept the view expressed by one member of the Institute, that coal is simply the property of the coalowners and of no one else. If we must live on our capital let us throw it away as little as possible, and let us look forward to those unfortunate generations who have to come after us. They will probably look back with regret upon the horrible waste of coal, which can never be replaced.

Mr. W. Brooks: I beg to thank you for the very excellent address you have delivered. I am in full accord with it all through, and although your reference to Protection may create some little friction, yet when some time ago a paper was read here strongly advocating Protection, no one blamed the author for introducing political subjects, and I am pleased that we have to-night heard the other side of the question. I quite agree that coal should be converted into gas. I believe out of 170 electric generating stations last year, the cost was ·95d. per unit. I know it can be placed on the switchboard by engines driven by Mond gas at ·048d. per unit, and there is no waste in smoke. That is a considerable economy.

The vote of thanks to the President was carried with acclamation.

The President: I assure you that I fully appreciate the vote and the sentiments expressed. In touching upon the question of Protection, I studiously avoided reference to individual cases, and the view I took was purely how it would affect the nation generally, and I certainly did not take into consideration how it would affect the coal proprietors, the coal consumers, or even myself, but viewed the matter purely from a national standpoint. The working class of this country forms about 75 per cent. of the whole population, and as Englishmen I do not believe that anyone of us would wish to change the conditions under which they are at present living for the conditions at present experienced in those countries where Protection is adopted. Mr. Jones states that we could not expect any aid from the State, but I do not at all agree, as the nation's affairs are in the hands of the nation, and there are means by which we can obtain reasonable assistance by the State in matters of such vital importance, and if reasonable pressure in brought to bear, I am convinced that such reformation may be brought about in some of the existing laws of our country, as will materially strengthen our position

to compete successfully with our neighbours. There are still further opportunities within our reach as regards fuel, and until we utilise all the energy stored up in coal we have not resorted to the one great economy so important in competition. Another very important consideration is the cost of conveying our goods to seaport towns by means of railways and canals, and there are many inequalities and monopolies which should be broken down. Most of you are familiar with the difficulties to which I refer, and the demands which the railway companies and the canal companies are able to make by Parliamentary authority will sooner or later have to be modified, otherwise a very great proportion of the trade of this country will be driven into the hands of those countries where the traders have such an enormous advantage over us in this particular. It is not an unusual thing for the traders to reduce prices to increase the volume of business, and if the railway and canal companies would fully recognise the necessity of some such reform in their business, there is no doubt it would provide one of the most valuable influences possible to the advancement of many branches of industry throughout this country.

The Second Meeting of the Session was held in the Metallurgical Lecture Room of the Municipal Technical School, Birmingham, on Saturday, the 29th October, 1904.

THE PRESIDENT (Mr. H. B. TOY) presided.

The minutes of the previous Meeting were read, adopted, and signed.

Mr. Eusby Chapman was elected a member of the Institute.

THE PRESIDENT introduced Mr. J. H. STANSBIE, who said that as the members had the printed paper before them, and he wished to devote most of the time at his disposal to the practical demonstrations, he would only read portions of the paper, and asked them to take the rest as read.

ELECTRIC SMELTING OF IRON AND STEEL (WITH PRACTICAL DEMONSTRATIONS).

By J. H. STANSBIE, B.Sc., F.I.C.

It is well known that an electric current carries electrical energy, and that this energy may be used to do mechanical work, to effect chemical decomposition, to bring about magnetic changes, and to produce heating effects. Electrical energy under control is an artificial production, and is generated at the expense of some other form of energy, which disappears in exact proportion as the electrical energy appears. The only apparatus at present available for its production on a large scale is the dynamo, and this may be described as a machine into which the mechanical energy of a moving fly-wheel, or of a rotating turbine is poured, there to be converted into electrical energy, ready to pass out of the machine with the current generated by its motion. This energy may be utilised either close to or at a distance from the generator. The condition that it may be carried through long distances, with comparatively small loss, is that a sufficient body of conducting material shall be used for its transmission.

The first principles of the dynamo are simple, but much care and experience are required in the selection of the materials for, and in the construction of an effective machine. By this is meant the machine in which the largest proportion of the mechanical power used in driving it is converted into useful electrical energy delivered at its terminals.

It may be stated generally that there are two types of current generators—direct current dynamos and alternators.

In machines of the first type the effective parts are so arranged that a practically continuous current flows through an outside conductor connecting the two terminals, or brushes, which press upon the commutator. That is, the main current is always in one direction, for one terminal is constantly at a higher potential than the other, and the convention is that electricity flows from points of higher potential to points of lower potential through the conducting bodies joining them.

In machines of the second type the arrangement is such that the current constantly ebbs and flows with a concertina-like motion in the conductor joining the terminals, so that, in effect, the main current consists of a series of currents in opposite directions. This is the result of the everchanging potential of the terminals; when if the potential of

one is high that of the other is low, and they change alternately, so that the curents passing between them alternate in direction

Both dynamos and alternators are almost the same in principle as the simple magneto-electric machines used for medical purposes. Coils of insulated copper wire are moved in one or more magnetic fields in such a way that the magnetic lines of force in the field are cut by the coils. Or, the coils are stationary, and the magnets producing the field are rotated to effect a similar cutting of the lines of force. This cutting of the lines of force causes a difference ot potential between the ends of the coils, and this difference depends upon the number of lines cut in unit time. Thus 10^8 lines cut per second give the practical unit difference of potential. Since the motion is a circular one, a given coil must alternately approach and recede from a given point in the field, so that the lines at that point are cut alternately in opposite phases, with the result that the direction of difference of potential due to approach is opposite to that due to withdrawal; thus currents in opposite directions circulate in the coil, and leave the machine by its terminals. With direct-current machines the currents are all brought into one direction by the commutator; but in alternating-current generators they are allowed to flow as they are generated. Alternators may be either monophase or polyphase according to the number and arrangement of the coils. A pair of leads may be used for each phase, or they may be combined with a common return. Thus with a three phase machine the three pairs of leads may be used separately, or in combination.

Although direct-current machines are used for smelting work, it is usually on a small scale. Alternating machines are more effective, and more economical for heavy work. An important difference between them is that wlth alternators the difference of potential may with safety reach 16,000 units, but with direct-current machines the limit is about 2,000 units. We have then in these machines generators of electrical energy, and it is probable that the limit of their size and power has not yet been reached.

The two factors of electrical energy are electro-motive force and quantity of electricity. The former may be likened to a pressure which produces, or is ever ready to produce, a flow of electricity through a conductor, and against the resistance of the conductor. It is also known as difference of potential and as electric pressure, and is easily measured. The unit of electrical pressure is the *volt*.

The resistance of a conductor is also measurable, and its unit is the *ohm*.

The unit of current strength is defined as the current which passes through a resistance ot one ohm under a pressure of one volt. It is called the *ampere*.

The definite relation between these quantities is known as Ohm's

Law, after its discoverer, and, when the units are properly correlated, may be written in the form:

$$\text{Current} = \frac{\text{Pressure,}}{\text{Resistance,}} \text{ or, Amperes} = \frac{\text{Volts.}}{\text{Ohms.}}$$

For the current strength is directly proportional to the pressure which produces it, and inversely proportional to the resistance to its flow. Using C for amperes, V for volts, and R for ohms, we have:

$$C = \frac{V.}{R.}$$

Now, the energy, E, carried by a current is directly proportional to the pressure and to the current strength, and its value in symbols is given by:

$$E = CV.$$

Also, by Ohm's Law, $V = CR.$

Therefore, $E = C \times CR = C^2R.$

That is, the energy is proportional to the square of the current strength, and to the resistance. But, if the energy carried by a current does no outside work, it is entirely converted into heat, H, in the conductor.

Therefore, H is proportional to $C^2R.$

The unit of electrical energy is the *watt*, and is the quantity carried by one ampere under a pressure of one volt.

Joule determined the relation between the energy of a given current and the heat developed in a resistance through which it flows. He found that a current of one ampere, flowing for one second through a resistance of one ohm, that is one watt-second, develops 0·24 calorie of heat.

$$\text{Therefore } H = C^2R \times 0{\cdot}24 = CV \times 0{\cdot}24.$$

Using the grain-unit of weight, we find that one watt-second would develop sufficient heat to raise 3·7 grains of water through 1°C.

Joule also proved that the quantity of heat required to raise the temperature of 1lb. of water through 1°C would, if expended in doing work, raise 1,390lbs. weight through a vertical height of one foot. This is known as the mechanical equivalent of heat. If, however, 1°F is taken as the rise in temperature, the mechanical equivalent is 772 foot-pounds.

Also, James Watt estimated that a horse working for one second would raise 550lbs. through a vertical height of one foot. Therefore, 1 h.p. working for one second would develop sufficient heat to raise the temperature of $\frac{550}{1390} = 0{\cdot}395$lbs, or 2,765 grains of water through 1°C.

$$\text{Therefore, 1 h.p.} = \frac{2765}{3{\cdot}7} = 746 \text{ watts.}$$

This gives the relation between mechanical energy and electrical energy.

The watt is, however, too small for a working unit, so the kilowatt, or 1,000 watts, is in common use. The kilowatt-hour is the Board of Trade unit of supply. The kilowatt is sometimes called the electrical horse power, E.H.P., and it is equal to $\frac{1000}{746} = 1{\cdot}34$ h.p. A simple calculation shows that a kilowatt-hour would, if converted into heat, raise 22½lbs. of water from the ordinary temperature to the boiling point; or, taking the specific heat of cast-iron as 0·11, and its melting point as 1,200°C, would melt 14⅘lbs. of cast-iron. That is 155 k.w. hours per ton.

In describing large operations some electro-metallurgical writers use the term k.w. year, but in such a loose fashion as to be somewhat misleading. Its value evidently depends upon the number of working hours in a year, which is given by one writer as 7,000 and by another as 8,400. It would be much simpler if a power of 10, say 10,000, were taken for this large unit; in which case it would be equivalent, theoretically, to the fusion of about 61 tons of pig iron.

The actual cost of electrical energy depends upon the cost of the mechanical power used in its generation. Now, when it is remembered that probably less than 5 per cent of the heat equivalent of the chemical energy in the coal burnt in the fire box of a steam engine is converted into the mechanical energy of the moving fly wheel, and that further loss must take place in its conversion into electrical energy, however perfect the dynamo, it is seen that this is a costly method of heat production. Clearly it is only allowable, when it is either impossible or inexpedient to obtain the result by direct combustion.

As the difficulties attending the use of common producer gas in the cylinders of gas engines are overcome, the cost of mechanical energy obtained by combustion will be considerably reduced; and by the use of the waste gas from the blast furnace, a further reduction may be predicted. It is in this direction that one must look for the application of the electric furnace to the iron and steel industry in this country. The waste of power in large ironworks must be very considerable, for Mr. H. Allen, C.E., states that four times as much energy could be developed by burning the waste gas in gas engines than is obtained by its use to raise steam, as is now so very largely practised.

At present the ideal source of mechanical energy for conversion into electrical energy is in falling water, and wherever this can be utilised there any industrial application of electricity can be made at a cheap rate, and cheapest where the cost of controlling the water supply, and of delivering it to the turbines, is least. If the difficulties of channelling and storage are great, and the capital charge heavy, the price of the power must be proportionally great.

These are the sources of energy at present under control, and which

men must be content to use until some genius teaches them how to use the power of the sunbeam direct, without having to wait for it to store its energy in evaporating water, or in growing plants. They will then be made independent of the configuration of the country in which they live, and upon which the use of water power so largely depends.

One of the first, if not the first, applications of electricity to the treatment of iron is found in the experiment made by Pepys in 1815. He split a piece of iron wire, and placed diamond powder in the gap, keeping it in place by closely binding the split portion with thin iron wire; he then passed a powerful current from a battery through the wire, and thus raised it to a bright red heat. In six minutes the diamond had disappeared, and the iron was converted into "blistered steel." A modification of this experiment is before you.

In 1849 Despretz used a tube of sugar carbon, which he succeeded in raising to a white heat by passing a strong current through it. Oxide of iron mixed with carbon, and placed in the tube, is rapidly reduced to the metallic state. Here is the experiment. The source of the heat in the wire and in the tube is the energy of the current passing through them, and the generation of the heat is due to the resistance of the bodies through which it passes. In the original experiments the voltaic battery was used, and zinc dissolving in dilute acid was the source of the energy.

It was not until 1867, when the residual magnetism of soft iron was first taken advantage of in the evolution of the dynamo, that a sufficiently powerful and economical source of electrical energy was rendered available for experimental work on a large scale. In 1878 Siemens introduced his electric furnace for steel melting, and since then much work of an electro-metallurgical character has been done even in the domain of iron and steel. The limits of this paper will, however, only allow of reference to the more successful of these efforts.

The extremely high temperature of the electric arc was recognised at an early date, for we find that Sir Humphrey Davy was experimenting with it in the early years of the last century. The most refractory metals are melted when exposed to it, and many stable compounds are reduced to the metallic state; for its temperature is probably between 3,000 and 4,000°C. The principle of the arc is very simple; the positive and negative terminals of the generator are connected by leads with carbon rods of sufficient diameter to carry the current. These are brought together and then separated, when, if the difference of potential exeeds 40 volts for direct current, and 30 volts for alternating currents, the gap is bridged over, and a continuous arc is the result. The effective distance between the carbons depends somewhat upon the strength of the current, but also upon the quantity of conducting vapour in the space between them, and may vary from the fraction of an inch to several feet. The greater part of the work is done upon the carbon connected with the high potential or positive terminal. This consists

for the most part in the volatilisation of carbon from the positive electrode to form a bridge for the current, and it is where this takes place that the major portion of the heat appears. The most remarkable feature of the arc is the concentration of the heat; for it is possible to hold the finger within a few inches of a space in which platinum is in a state of fusion.

Another method of generating heat for metallurgical purposes is based upon the production of induced currents in a secondary circuit. It is well known that when the direction of a current in a primary conductor is reversed, a current is set up in a secondary closed circuit near to it; this induced current is only momentary, but a second reversal sets up another secondary in the opposite direction, and by rapid reversals of the primary a series of secondary currents are set up in the secondary circuit, but opposite in phase to the primary series. The effect of the primary upon the secondary circuit is increased by the insertion of a soft iron core in the primary coil. This will be recognised as the principle of the transformer used to transform alternating currents of high voltage and low amperage, which have been transmitted to a distance, into the powerful currents of low voltage required for lighting and other purposes.

If the resistance of the secondary circuit is large, it is raised to a high temperature, and the heat thus developed may be used to do metallurgical work. The welding machines now coming into use, and for which alternating currents are necessary, are based upon this principle.

The general principles stated above are all taken advantage of in the construction and working of electric furnaces, which fall naturally into three types.

(1) Electric arc. (2) Electric resistance. (3) Electric induction.

(1) *Arc Furnaces.*—In these furnaces an electric arc is formed in the air space between two or more electrodes connected with the positive and negative leads from the generator. The electrodes are usually massive rods of conducting carbon, and are never in contact with either the solid or liquid matter under treatment in the furnace. A minimum pressure of 40 volts for direct, and 30 volts for alternating currents is required to form the arc, which is easily done by bringing the two carbons together, and then separating them, or by bridging the space between them with a separate piece of carbon, and then removing it. The intensely high local temperature is in the neighbourhood of the positive carbon with direct current, and first near one and then near the other with alternating currents. When the arc is working, the materials in the furnace are heated both by direct radiation from the arc, and by reverberation from the sides and crown of the furnace. The arc furnace is the oldest form of electric furnace, and the simple contrivance of M. Moissan, in which he has done much excellent experimental work, con-

sists of two chalk or limestone blocks bored in the centre,a carbon crucible, and two thick carbon electrodes. An arc furnace of simple construction is on the table before you. See Fig. 1. It is intended for arc heating in shallow crucibles, and to increase the effect the arc is drawn down into the crucible. This is effected by a coil of insulated wire passing round the furnace in the same vertical plane as the carbons, and fed from the main current. Its action is due to the fact that separate conductors bearing currents in the same direction attract each other, and in opposite directions repel each other. Thus when the furnace is working the effect of the current in the lower part of the coil upon the current through the arc is to attract the arc down into the crucible, and the effect of the current in the upper part of the coil is to repel the arc downwards. Thus the upper and lower parts of the coil produce the same general effect. A powerful magnet may also be u ed for the same purpose. The working of this furnace will be made clear to you directly.

The *Stassano* furnace is the best illustration of the application of this type to the smelting of iron and steel, and a careful study of its evolution from the crude furnace used by Mr. Stassano in 1899 to its present form should prove useful to those with a leaning towards the arc-smelting of iron ores. The original furnace resembled a small blast furnace in form and working; the latest form resembles a reverberatory furnace with a revolving bed, and is now being worked under the auspices of the Italian Government at Turin, although Mr. Stassano did most of his work at Rome and Darfo.

The furnace is circular in cross section, and the reduction chamber, which is 39in. in diameter and 39in. high, has a dome roof. It is lined with suitable refractory material, and the carbon electrodes, about 9in. in diameter, enter the chamber through openings about midway between the floor and the roof. The electrodes are fitted with regulating gear by which they can be caused to meet in the centre of the chamber, or their ends may be brought flush with the walls. There are tap holes for the metal and slag, one near the bottom of the hearth, the other about midway between the bottom and the electrode openings. The parts of the electrodes outside the chamber are water jacketted. The hearth is rotated on an axis slightly inclined to the vertical, so that one side of the chamber is always a little lower than the other, and a kind of rabbling motion is set up in the charge, the refining being assisted thereby. The electrodes rotate with the chamber, and proper contact with the power leads is kept up by an arrangement of brushes connected with the axis over the top of the chamber. The charge is fed in through a hopper and inclined shoot, which enters the chamber a little above the electrodes.—See Fig. 2.

The ore, which is the pure variety found in Northern Italy, is ground fine and carefully mixed with calculated quantities of limestone and

coke, or charcoal, some bituminous binding material is then added, and the mixture pressed into briquettes. The proportions are said to be—ore 100, limestone 12½, carbon 16, hydro-carbons 12. This care is taken in order to keep the smelting mixture uniform, although it is said that the pressing into briquettes is not necessary to successful working.

When the furnace is uniformly heated the arc is about 3ft long, and very noisy. The charge is heated by direct radiation from the arc, and from the sides and dome of the chamber. An alternating current of 2,000 amperes at a pressure of 170 volts is used, so that energy at the rate of 456 h.p. passes into the furnace. This renders possible the reduction of the ore by the carbon of the charge, the formation of the slag, and the fusion of the metal and slag. About 3,000 kilowatt-hours are required for every ton of metal produced, and the total cost is estimated at £3 15s. per ton. The output is rather small, 2½ to 3 tons of steel per day, and the metal is said to be about equal to good open-hearth steel. Another estimate gives the output at 1½ to 2 tons per day, using 1,000 amperes and 80 volts.

The original furnace was intended to produce pig iron, and its failure under the most favourable conditions of cheap ore, cheap water power, and cheap labour, seems to indicate that the electric arc furnace is hopelessly outclassed by the blast furnace for the production of pig iron, although it may compete under certain conditions with the blast furnace and the open hearth in the production of good quality mild steel. Water power only is used, and there appears to be no arrangement for utilising the waste gas from the furnace, although its principal constituent is carbonic oxide.

Mention should be made of the *Siemens* arc steel melting furnace, which he introdued in 1879, and in which he succeeded in melting several lbs. of steel. It consists of a crucible, through the sides of which the two electrodes pass. The positive electrode is of carbon, and the negative of hollow metal water cooled. A direct current was used for working it.

(2) *Electric Resistance Furnaces.*—In these furnaces the heat is generated by the resistance offered to the passage of a powerful current by part or the whole of the furnace charge.

This form of furnace has been developed to a remarkable extent by M. Keller of the Livet Works, France. A description of his latest furnace, and the process generally will serve to illustrate this method of working. The complete apparatus may be described either as a double furnace or as a shaft furnace with a separate hearth. See Fig. 3. The shaft is fitted with a cup and cone for charging, and there is a take off for the furnace gas, which is largely made up of the carbonic oxide formed during the reduction of the ore. The shaft opens at the bottom into a low-roofed chamber, and the massive carbon electrodes pass through apertures in the roof at the side of the shaft. The gap between the electrodes on

opposite sides of the furnace is bridged over by the hot solid portion of the charge, which has reached that part of the furnace, and the current passes. The reduction of the oxide of iron takes place; the reduced iron fuses, and the slag is formed. Much of the ore is probably reduced by CO in the upper zones of the shaft. The liquid matter forms two layers in the chamber, metal underneath and slag at the top. The molten slag takes part in the transmission of the current, and forms part of the effective resistance. Tap holes at different levels are arranged for the slag and the metal, and care is taken not to let the slag rise too high, as it not only exerts a corrosive action upon the electrodes, but also affects the purity of the metal. It may be noted here that metallic oxides and silicates, which are practically non-conductors when cold, become conductors when heated, and thus offer the necessary resistance for the generation of heat. This principle is applied for lighting purposes in the Nernst lamp.

The electrodes, which are four in number, are joined in pairs, and are connected in parallel with the leads from the generator. Each electrode is connected separately with a pulley arrangement, so that its position can be altered, or it can be replaced without disturbing the others, or breaking the circuit. Thus if one of a pair is removed the other takes the load for the time being, and the furnace continues in action. This is very important in connection with hydro-driven furnaces, for the sudden removal of a big load is bad for the turbines.

The metal is tapped into a separate furnace, which represents the fore hearth, and there it undergoes a refining smelting. Two or more carbon electrodes pass through the low roof of the hearth, and come into contact with the layer of slag, which must cover the metal. This serves as the resistance layer in which the necessary heat is generated, and also brings about the refining of the metal, for its composition can be easily regulated by the addition of oxidising and basic materials. Care is taken to keep the electrodes well out of contact with the metal, and they may be almost out of contact with the slag, so that short arcs are formed between them and the slag surface. The metal is tapped, and run into ingots, when the refining is finished.

With regard to the cost of working, the last figures given by M. Keller are 1,200 h.p. passing into the furnace, giving 2,800 k.w. hours per ton of metal. Total cost per ton, 72-80 shillings. Further, he says that with 10,000 h.p. on the shaft of the turbine he could produce 60 tons of steel per day. For this he would place two fining furnaces in front of a reducing furnace; or, tap the reduced metal from a number of furnaces into one large finery.

M. Keller has recently patented another furnace, which he describes as a plurality of hearths communicating with a central crucible placed at a lower level. An electrode is inserted through the top of the crucible portion, and can be used at will for reheating purposes. Iron

ore, coke, and flux are supplied to the hearths, and the reduced metal runs into the crucible, where lime may be added for the removal of phosphorus, air blown in to produce an oxidising action, and reheating effected, if necessary. Polyphase currents may be used if one hearth is used for each phase. The soles of opposite hearths are connected by thick copper rods, which gradually come into the circuit as the metal is tapped from the crucible. The load is thus kept fairly constant during the working, and injury to the turbines avoided. There is no information to hand of the cost of working this furnace; but it will probably fail, as far as the economic reduction of iron ores is concerned.

The *Hèroult* refining process is, perhaps, the best and most successful application of electricity to the metallurgy of iron. The furnace resembles a small tilting hearth; it has two massive carbon electrodes passing through the top, and connected with the power leads. The process is intended for the conversion of cast-iron and best scrap into best quality tool steel. The hearth may be lined with non-carbonaceous refractory material, which may be either acid or basic in character. See Fig. 4. The cast metal is run into the hearth in the molten state, and the scrap added. The electrodes are then brought into contact with the surface of the slag. The presence of slag, or other material whose conductivity increases with the temperature, is essential. The electrodes just dip into this, and the conditions are such that the slag just under the electrodes gets hotter than that between them, so that the current passes largely through the metal underneath, The electrodes must be kept out of contact with the metal, or the refining is interfered with. By tilting the hearth the slag may be run off, and more slagging material introduced to finish the refining. In this way two or more "washings" may be effected. The refining is very effective, and the content of carbon appears to be under control.

Dr. Hèroult says that he delivered about 9 tons of steel in 9 cwt. bars, made in his electric furnace at Froges, to Messrs. Schneider and Co., of Creusot, in December, 1900; and he claims that he can make best quality tool steel from cast iron and scrap in 3 ton charges. His furnace was worked by alternating currents of 4,000 amperes at a pressure of 60 volts, that is 240 kilowatts or 322 h.p. He further states that 2,500 tons have already been produced in France, and that by the end of the present year plant having a capacity of 400 tons, and capable of turning out 150 tons per day, will be in operation.

This furnace has already found its way into Sweden, where it is now working; and it is to be used in connection with a German electrical installation, in which waste gas from the blast furnace is to furnish the motive power.

The following is a typical analysis of steel made in the furnace:—

S = ·016; P = ·006; Si = ·02; Mn = ·092; C = 1·08.

The carbon may be varied from 0·6 to 1·87.

M. Gin has constructed a furnace in which he melts iron and steel, by causing the charge of metal itself to interpose the resistance necessary to obtain the melting temperature. The bed of the furnace has a channel in the form of an elongated horse shoe, the open ends of which are closed by carbon blocks connected with the power leads, and it is in this channel that the melting and refining is effected.

(3) *Electric Induction Furnaces.*—These furnaces, although novel in construction, present nothing new in principle. They are in effect transformers of the type used for reducing the voltage of the high potential currents generated for transmission through long distances to the low potential currents required for lighting purposes, and in large modern welding machines. They can only be used with alternating currents.

The *Kjellin* furnace is the most successful of this type. It is doing good work at Gysinge Bruk, in Sweden, and has been in operation there since 1900. It appears to be admirably adapted to its surroundings.

The furnace is circular in section, and the hearth consists of an annular space in the masonry, lined with either acid or basic material, and fitted with a cover and a tap hole. In the centre is placed a massive iron core made of a number of thin soft iron plates.—See Fig. 5.

This core is surrounded by a coil of insulated wire of many turns to form the primary circuit. The metal to be melted and refined is put in the annular hearth, and forms the secondary circuit of the transformer. Alternating currents of 80 to 90 amperes, at a pressure of 3,000 volts, pass through the primary coil, effect rapid magnetic changes in the iron core, and set up a series of induced currents of 30,000 amperes at 7 volts in the ring of metal in the hearth. The resistance of this metal to these powerful currents raises its temperature above the melting point, and refining can be effected. The charge consists of good charcoal iron and scrap. No furnace gases come into contact with the metal, and a product of high purity is obtained. Iron alloys can be added to produce special steels.

The most recent furnace is 12 feet in diameter and 8 feet high, and has a capacity of 35 cwts.; 20 cwts. of finished metal are tapped from the furnace every four hours, and 15 cwts. left in to continue the transforming while the fresh charge is added. The cost for power is said to be eleven shillings per ton of steel produced.

Good homogeneous metal of tool steel quality, which forges well, is produced, and Mr. Ritchie, of Glasgow, to whom the figures given above are due, speaks highly of the process after having watched three

charges worked off, and analysed samples from different parts of the ingots produced. One analysis he gives is as follows:—

P = ·015; S = ·012; Si = 093; Mn = 0·44; C = 1·33.

It would appear from a consideration of the processes described above, that the electric furnace will be entirely outclassed by the blast furnace as long as cheap coke can be obtained; but that the crucible steel making industry will be considerably influenced in the near future by electric smelting methods. Still the electric smelting of iron ores will probably be successful, and have a long life in out of the way districts, where iron ore is found, water power abundant, and where fuel would have to be imported for its smelting. This will be especially so in countries in which, on account of heavy freightage and high tariffs, the price of imported iron is almost prohibitive. Examples of such are already to hand.

In Brazil a comparatively pure ore can be delivered at 10s. 6d. per ton; also, there is a waterfall, 114 feet high, which can be used to work turbines supplying 25,000 h.p. in the season of minimum flow. It is said that the cost of one h.p. per year will be less than 10s., and that a kilowatt-year, which when properly utilised in an electric furnace, will produce 4 tons of good mild steel, at a cost of less than 25s. As the price of coke in this district is 48s. per ton, and there is a prohibitive tariff on imported iron, the electric smelting plant, which is being put down near the water supply, should have a successful career. Facilities of a similar character are found in Chili.

The iron sands of New Zealand have so far resisted efforts to smelt them, but M. Keller has shown that they can be treated in the electric furnace, and he says that on account of the formation of a highly basic slag, made possible by the hot working of the furnace, he was able to produce an iron free from titanium, for the titanic acid all passed into the slag. Mr. A. H. Allen, of Sheffield, is of opinion, from his own work with titaniferous ores, that the reverse is the case in the blast furnace; for he found that an acid slag was most favourable to the elimination of titanium, and that the introduction of much lime caused trouble. It is evident from this that the conditions in the two furnaces are quite different. Titaniferous ores are always troublesome in the blast furnace, and a method of successfully treating such ores, where they are found in abundance, would be useful.

Iron Alloys.—It is in the preparation of iron alloys that the electric furnace has scored up to the present, and will score in the future, its most important successes. Take ferro-chrome for example. At one time it was produced entirely in a small cupola; but difficulties were always experienced owing to the furnace becoming choked. Often it became necessary to partially take down the furnace so as to remove the obstructions. Now it is readily obtained at the higher temperature of

the electric furnace; and further, the ore can be smelted on a carbon hearth, as the presence of carbon in the alloy is not of consequence. Alloys containing about 60 per cent. of chromium and 8 per cent. of carbon are common. Ferro-tungsten, ferro-nickel, and other ferro-metals can be obtained in a similar manner; and these alloys are now of great importance in steel making.

Mr. A. J. Rossi, in an interesting communication to the New York section of the American Electro-Chemical Society in January last, says that the temperature conditions of the blast furnace are not sufficient for the reduction of the more refractory metallic oxides, and even those which are now smelted in it can be treated quite as economically in the electric furnace, with cheap current and proper materials.

Oxides of titanium and vanadium are the most difficult to reduce, and these are followed by the oxides of tungsten and molybdenum. The ferro-metals are, as a rule, more fusible than the metals themselves, and the presence of carbon in the alloys also influences their melting point.

The natural oxides, which are usually associated with more or less oxide of iron, are finely powdered, mixed with the proper proportion of carbon, and smelted in an arc furnace of the Siemens type. The result is an alloy of the metal and iron containing some carbon, which may be partially removed by a refining smelting. If, however, carbon is inadmissible in the alloy, another metal must be used as a reducing agent. Aluminium is the best for this purpose on account of its great heat of combination. Dr. Goldsmidth's method of reducing refractory oxides by means of finely divided aluminium is well known, and probably suggested to Mr. Rossi the process he now adopts for obtaining these alloys with only a small percentage of carbon. He runs down either ingot or scrap aluminium in an electric furnace, and so gets a bath of the molten metal; he then adds the oxide to be reduced, and so regulates the current that the temperature does not rise too high during the intense reaction between the metal and the oxide. The slag, which is principally alumina, is run off, and the alloy purified by the addition of oxidising material before casting.

By using ferruginous ores of tungsten, chromium and molybdenum, ferro-tungsten up to 78 per cent. tungsten, ferro-chrome up to 65 per cent. chromium and ferro-molybdenum, are obtained. In preparing ferro-titanium Rossi found the well-known titanium mineral rutile too expensive for ordinary use, and he succeeded in obtaining an artificial rutile by smelting titaniferous iron ore with a little lime, and just sufficient carbon to reduce the iron oxide. The titanium oxide passes into the slag together with a little iron, and this slag is reduced by aluminium for the production of ferro-titanium, or it may be reduced by carbon if the presence of the latter in the reduced metal is not objectionable. Titanium is said to increase the strength of cast-iron upwards of

30 per cent., and to increase the elastic limit of steel. But this is not in accord with experience in this country.

The use of aluminium for the reduction of pure oxide of iron in a furnace of the Kjellin type should solve the problem of obtaining carbonless iron for experimental purposes. A small induction furnace, with a basic lined hearth of a few pounds capacity, should be able to furnish either the pure metal or alloys of controlled composition, and the questionable method now in use of determining the influence of a particular element on the physical and mechanical properties of iron in the presence of other elements would be avoided.

Mr. E. A. Sjöstedt, of Sault Ste Marie, Ontario, describes, in a paper read before the American Electro-Chemical Society, an electric smelting process for the production of ferro-nickel from nickeliferous magnetic pyrites. The process was proved to be successful, but was abandoned in favour of the combined blast furnace and open hearth method on account of the cost of the large electrical plant which would be required for the projected output. Mr. Sjöstedt has, however, taken out patent rights for the final form of electric furnace used in the experiments.

The ore, which was hand picked to separate the cuperiferous portions as completely as possible, was roasted down to about 3 per cent. S, and smelted in admixture with excess of lime and sufficient ground coke to effect the reduction. The patent furnace is a rectangular chamber cased with iron plates and lined with magnesia bricks. It is furnished with a movable bottom which can be taken out and replaced as required, and one of the electrodes, a rectangular carbon rod, is fitted in this bottom in the direction of its length. The other electrode consists of a number of rectangular rods arranged in a row vertically over the lower one, and capable of a vertical motion. The slag notch and tap hole are at opposite ends of the furnace, which is supported on pillars, to allow of the ladle being run underneath. There is a port for carrying off the waste gas, and doors for working.

From the general arrangement, the furnace is evidently of the resistance type, and the current passes through the slag and the metal, the resistance of which furnishes the necessary heat. The composition of the charge is given as—roasted ore 100, lime 150, and coke 25. The slag and metal are tapped at intervals. The large excess of lime is necessary for the removal of sulphur, which is said to be brought down to 0·02 per cent. in the finished alloy. The furnace working with 1,350 amperes at a pressure of 80 volts, or 108 kilowatts, had an output of 13cwt. of alloy per 24 hours, and was said to show a profit of 20s. per ton on the metal produced.

Ferro-silicon.—The preparation of this important alloy in the electric furnace has already assumed considerable proportions, both on the Continent of Europe and in America. The well-known reaction which

takes place when a mixture of silica, carbon, and iron is raised to a high temperature is used under the favourable conditions of the electric furnace, and a product high in silicon is obtained. Specimens containing various percentages of silicon up to 98 per cent. are put on the market; but the richer alloys are not likely to be in much demand. The most important use of ferro-silicon is that of a softener in the foundry, and Professor Turner is of opinion that operations in which rich alloys are used are not readily controlled in ordinary practice, which is very important to the foundryman.

M. Keller has produced ferro-silicons in considerable quantities at the Livet Works. He uses scrap iron, quartz, and coke in the smelting mixture, and carries out the smelting in a resistance furnace. Very little slag is formed during the working, which is found to be an advantage. Crushed quartz gives a better result than silica sand, and scrap iron than ore. The furnace takes about 150 h.p., and the production of one ton of 30 per cent. ferro-silicon absorbs 3,500 kilowatt-hours. M. Keller estimates that a hydro-electric works developing 10,000 h.p. upon the shaft of the turbines would be able to produce 16,000 tons of the 30 per cent. alloy per annum, or nearly 30 tons per day.

M. Gin, who has had much experience in electric smelting, has patented a process for the manufacture of ferro-silicon and ferro-manganese simultaneously with the production of alkaline and alkaline earthy oxides. The changes he relies upon for the production of ferro-silicon and baryta are expressed in the following equations :—

(1) $BaSO_4 + SiO_2 + C = BaO.SiO_2 + SO_2 + CO.$

(2) $BaO\,SiO_2 + Fe_2O_3 + 5C = Fe_2Si + BaO + 5CO.$

The operations are carried out separately in an electric furnace, and elaborate apparatus is used to absorb the sulphur dioxide, and convert it into sulphuric acid. The success of this process evidently depends upon the demand for its various products.

A very ingenious electric furnace has been devised by Ruthenburg for the agglomeration of magnetic iron sands, and is in use in America. It consists essentially of two iron hoppers, which are magnetised by coils round their upper portions. The lower ends are so arranged that the magnetised particles of ore which are delivered from them, cling together and form a resisting bridge across the gap between their ends, so that a strong current passes, and raises the temperature of the particles sufficiently to cause them to stick together, and to lose their magnetism. The pasty mass then drops, and the gap is bridged over by fresh material. The reduction of the ore is not effected electrically.

One of the chief causes of the recent activity in the electric smelting of iron and steel is to be found in the decline of the calcium carbide industry. Managers of hydro-electric works found themselves with

much power running to waste, and endeavoured to use it in other directions. The carbide furnaces were found to be more or less suitable for the production of ferro-metals and ferro-silicon, and are being used for this purpose. In some cases the furnaces are worked first for carbide and then for ferro-silicon; this is evidenced by the fact that some samples of the alloy contain small quantities of the carbide, for when moisture comes into contact with them, acetylene is set free.

A fact which strikes one very forcibly in connection with electric-smelting is the large number of patented furnaces and processes one meets with; and it would appear from a description of them that the patentees do not waste much time in finding out what has been done already, and how well known and self-evident most of the principles are the application of which they seek to protect. One man alters the shape of a brick and rushes off to patent it; another handles this same brick while it is in the soft state, pushes his finger through it by accident, and hastens to patent the hole. Only the few seem to realise how simple are the principles and their application, and these are the men who are making their mark upon the industry, for the electric furnace is almost as simple in principle as the hoary shaft furnace still in use among the hill tribes of India. The one element of success is cheap power. With this the ordinary metallurgist, possessing a knowledge of electrical principles, and of furnace construction, can obtain any product of the iron and steel industry, without infringing patent rights in this or any other country.

The Demonstrations.

Diagrams of Current Generators.—The author stated that one of his colleagues had been kind enough to put on the blackboard two very simple diagrams illustrating the general principles of the two types of current generators, the one a simple direct-current dynamo and the other a simple alternating current dynamo. The wire coil could be rotated very rapidly between the two poles of the magnet. The result of the cutting of the magnetic lines of force by the coil was to set up an electric pressure, and the result of this pressure was to cause a current of electricity to flow through the wire. He explained that the chief point to observe about a direct current machine was that as the armature rotates, the different coils are either approaching or leaving a certain point in the magnetic field. The approach causes a current to be set up in one direction and the withdrawal causes a current to be set up in the opposite direction, but by means of a split axle or commutator, the two currents are caused to follow each other in the same direction, through the outside circuit. In an alternating machine, instead of this commutator we have two rings to which the two ends of the loops are fastened. He had on the table examples of these machines, which he

would be very pleased if any of the audience would come and examine after the paper. In one of the forms shown, instead of the coils moving, the magnets themselves moved, but this does not affect the general principle. As they would see from the paper, with direct current dynamos they could not develop a pressure of more than 2,000 volts without danger, whereas, in alternating machines, they could run up to 16,000 volts without danger.

Utilisation of Water Power.—A simple illustration of the way in which water power can be used for the generation of an electric current, for doing any kind of work was then given. The apparatus used was a small water-wheel and a direct current dynamo. Water running from a tap actuated the water-wheel which was connected to a dynamo, causing the latter to work. The emission of sparks showed that electricity was being generated He thought it would be interesting to see the kind of country in which water power could be utilised, and he put on the screen a view of a Californian hydro-electric station in which a very high power was generated. They would notice the rush of the water to a series of eight turbines. The next view was a French hydro-electric power house; and the next was a slide showing some alternating dynamos at work therein.

The Pepys Experiment of 1815.—As intimated in the paper, the author presented a modification of the experiment made by Pepys, in 1815, of converting iron into steel by electrically heating a piece of split iron wire, diamond powder (which is nearly pure carbon) being placed in the gap. The union of the iron and the carbon produced steel. The author pointed out that this was probably the first application of electricity to the iron and steel industry, and they would notice that the experiment had taken place nearly a century ago The wire in that case was made red hot by passing a powerful current through it. The diamond entirely disappeared in a few minutes and Pepys got blistered steel, that is, he had succeeded in converting soft iron into steel by bringing the iron into contact with carbon. By means of an electric furnace the author now successfully imitated the Pepys experiment, the soft iron being readily heated by passing an electric current through it, and the small piece of metal discharged from the furnace after the heating had taken place was decidedly of a steely nature, and was later on examined with much interest

The Despretz Experiment of 1849—The next experiment shown was one made by Despretz in 1849, which was also a rather early date for such an experiment. Despretz took a piece of sugar carbon and made it into a small black tube, of which the author had an imitation on the table Despretz filled the tube with bodies that he wished to deal with electrically, and then raised the temperature by means of a powerful current. The author repeated the experiment. The current used represented very nearly one horse power, and the carbon tube

was packed with a mixture of oxide of iron and carbon. A furnace of this type, in which the resistance was furnished by a mass of small coke between the electrodes, was shown in which some cast-iron was rapidly melted and run from a tap hole.

The Electric Arc.—The author next gave some illustrations of the development of heat by using a gaseous resistance, *i.e.*, the heat developed by means of the electric arc. They would find this matter explained in the paper, and he would now show them a good type of an arc furnace, namely, the Stassano furnace. A representation of this furnace was then thrown on the screen and explained. He would like to show them what could happen in an arc furnace so he had arranged one there. It was a little furnace of the Moissan type. It was an experimental furnace, but it gave a good idea of what could be done in the way of reduction. This experiment was very successful and was warmly acknowledged by the audience who, later on, had an opportunity of examining the ferro-chrome produced by it. During this experiment a consumption of energy equal to 6.000 watts was registered.

Melting of Crucible Steel.—Another furnace, in imitation of the Siemens electric furnace, was also shown in operation, in which best crucible steel was very rapidly melted, and in the course of this experiment the author pointed out that they were getting 115 amperes and 35 volts. He humourously remarked that although the apparatus showed the power of the furnace to melt very refractory material, yet he was afraid the apparatus would not be of any commercial value, for what people generally wanted nowadays was to change a cheap material into a more valuable one, whereas in this experiment best crcucible steel was being converted into grey cast-iron, which was doubtless just the opposite of what they would like. But that was because he was using a carbon crucible for one of the electrodes, and the carbon was passing into the iron very rapidly.

Copper Melting.—The next experiment was a very pretty one, some copper being melted, and the light from the furnace being reflected on to a screen on the opposite wall, so that the audience could see what went on in the interior of the furnace. The changing colours of the flame were reflected very successfully, and also the movements of the charge during the process of reduction. The author explained that the electric arc was being pulled down into the main crucible by the action of a shunt current upon the current which was passing through it. The instruments in the course of this experiment registered 70 volts and 100 amperes. The audience saw clearly on the screen the reflection of the carbon rods and also the evidences of the intense temperature that was generated between them.

Professor Moissan and High Temperatures.—The author stated that Professor Moissan had succeeded in getting the very high temperature of 4,000 degrees centigrade. When they considered that the

highest temperature obtainable by burning fuel in oxygen was probably under 2,000 degrees centigrade, they would see how high a temperature had been secured, and how useful it must be in the reduction of refractory materials. Moissan had estimated that he obtained from 3,500 to 4,000 degrees centigrade in one of his furnaces when he was using 1,200 amperes at a pressure of 100 to 110 volts in a furnace not much larger than the one then on the table. Temperature depended upon the space in which the heat was generated. In a very confined space they got a higher temperature. Moissan was able to fuse everything except carbon. He had proved conclusively that carbon is the most refractory substance we have. It had never been fused uuder ordinary pressure, though in all probability it did liquify if the pressure was very much increased. And it was by subjecting carbon to great heat and then to great pressure that Moissan and others had tried to produce artificial diamonds.

The Hèroult Refining Furnace.—Several views of this furnace were shown and the process explained.

Electric Induction Furnace.—A view of a novel kind of electric induction furnace was shown, the author pointing out that it was a circular furnace, consisting of a refractory substance which took the form of a ring. This was a furnace which could only be used with alternating currents. No furnace gases need come in contact with the metal, so it is possible to get a very pure kind of steel. A furnace like that might be used for the production of pure iron. Dr. Goldsmith's method of reducing refractory oxides is effected by means of aluminium. It had struck him (the author) that if alumininm were used in this furnace for the reduction of pure oxide of iron, it might be possible to produce an iron free from carbon.

THE DISCUSSION.

THE PRESIDENT: We are all, I am sure, very much indebted to Mr. Stansbie for his most valuable paper, which has been rendered so interesting by his practical demonstrations There are many technicalities in this paper which I shall not venture to discuss, but there are one or two matters in it which are very interesting to all of us, and to these I should like to make some reference. We have heard many times that there is an enormous amount of waste going on in our iron and steel works, and Mr. Stansbie quotes Mr. H. Allen, as stating that four times as much energy can be developed by burning waste gas from blast furnaces in gas engines than is obtained by its use to raise steam, as at present. I think you and I are thoroughly conversant with the number of pounds of coal necessary to convert a gallon of water into steam and with other axioms of steam-raising practice, but I believe the time is not far distant when the present steam formulæ will be

substituted by electrical terms, such as volt, ampere, and watt. I should like to mention here a humourous story I heard told by Dr. Andrew Wilson about the circulation of the blood. He had produced on the screen a section of the heart, one part coloured blue and the other red. A lady was explaining to her husband all about the lecture, and she said she had only discovered that night that one part of her heart was blue and the other part red. Well now, I hope none of us will go back to our homes and say we have learned to-night how to make cast-iron out of steel, because what we are all trying to do is to make steel out of iron. But, joking apart, I am sure we must really feel very grateful to Mr. Stansbie for bringing before us such an important matter as electric smelting. The first step to be considered is, how is the necessary power to be generated? and then, how to employ that power electrically? I know there are gentlemen in this room more able to discuss the matter than I am, and I have much pleasure in calling upon Professor Turner to open the discussion.

PROFESSOR TURNER: I feel very much indebted to Mr. Stansbie for the interesting paper to which we have listened, and to the authorities of the Technical School, including our friend Mr. Hiorns, for the facilities we have been granted. I remember, in America, two years ago I was very interested in the power station at Niagara, and also in seeing the electric smelting works which produced a very interesting material known as carborundum, which process is an example of heating by resistance. Several large furnaces, each about as long as this lecture table, twice as high, and twice as wide, were working quietly there making considerable quantities of a valuable product. Mr. Stansbie has covered a great deal of ground, and I think he has given us the truth when he observes, "The actual cost of electrical energy depends upon the cost of the mechanical power used in its generation." Where you can get waterpower cheaply, there is an enormous future for electrical energy. The whole of the commercial aluminium manufactured in the world is at the present time made electrically by the resistance furnaces in which there is also an electrolytic action. With reference to the production of rich ferro-silicon compounds, we have a number of samples of these at Birmingham University, and we shall be glad to show them to anyone who is interested in the matter. We can show you samples from various places on the Continent starting from about 10 per cent. up to 98 per cent. silicon. We also have some samples of ferro-aluminium made in the electrical furnace in the same way. I feel I have myself benefitted by hearing this matter so simply and plainly explained, and I am sure we have all been very much interested by the experiments to which Mr. Stansbie had treated us.

Mr. J. W. HALL: I know that alloys made in electrical furnaces are being practically used, and I have myself seen them used in various steel works. But my experience is that ferro-silicon containing 50 per cent. of silicon practically disintegrates after being kept for a time, so I

should like to know how specimens containing 90 per cent., such as have been spoken of are kept. I may say that a gentleman who understands the matter told me the other day that he considers that the electric furnace has a very great future before it.

PROFESSOR TURNER: I have some samples of ferro-silicon which have been kept a long time and have never exploded. They are as good now as ever they were, and are not even tarnished. The richest sample I have is practically pure silicon as it contains about 98 per cent. of silicon. But I have noticed with regard to some samples containing 35 per cent. of silicon, that when they are crushed in a mortar they emit an unpleasant smell which, perhaps, may be connected with the explosions which sometimes occur.

MR. HALL: Some I saw containing 50 or 60 per cent. disintegrates and fall to pieces on exposure to the air.

PROFESSOR TURNER: Put in a small wooden box, with some cotton wool round them, and kept inside a covered building, my samples have kept perfectly well with no special precautions.

MR. ISAAC E. LESTER: I am sure there is nothing I can add to the very excellent paper and demonstration given us by Mr. Stansbie. In the matter referred to by previous speakers, viz., that of the peculiar behaviour of high content ferro-silicon, I may say that I have known cases when not only this but ferro-manganese of high content, after being unpacked from casks or boxes, became in a short time so friable as to admit of being easily broken up by a wooden hammer or "beetle." In the examination of these alloys I frequently noticed indications peculiar to carburetted hydrogen, and which latter resolved itself under certain treatment into a wax of the paraffin series which, although in small quantity, was yet sufficient for identification. In the discussion at the last meeting of the Iron and Steel Institute it was shown that the explosions were due to phosphuretted hydrogen and not acetylene gas, while it was admitted that the electric furnace producing the ferro-silicon in question had just come off making calcium carbide charges. It is owing to the employment of electric furnaces that we can so successfully produce high content ferros and alloys which make it possible to produce high class steels, castings, etc., for very special purposes. Mr. Hiorns and Mr. Stansbie may remember that in the old school of metallurgy, 16 or 17 years ago, we tried ordinary wind furnace reduction of ferro-chromium from chromite, and while it was possible to get, by prolonged high temperatures, globules only of about 17 per cent. chromium-iron alloy we did not succeed in a general and easy reduction. The difficulty is now overcome, as has been very ably demonstrated by Mr. Stansbie in producing before us intensely high temperatures and special alloys of high purity.

Mr. JOSEPH COLLEY: I will not presume to take up any of your time, because the question I wanted to ask has been answered, namely, as to ferro-silicon containing over 90 per cent. of silicon, which I understood could not be successfully produced. I am delighted with what I have seen to-night. The experiments Mr. Stansbie has so ably demonstrated have been admirable, and well illustrate the march of progress in iron and steel matters. The high temperatures we have seen developed completely surprised even those who have been connected with the iron trade for many years. I can only offer my thanks to Mr. Stansbie for the admirable paper he has given us this evening.

Mr. ARTHUR H. HIORNS (Head of the Metallurgy Department): In the absence of the Principal I should like to say how very heartily we welcome you to our school to hear this paper. I hope it will not be the last time you will visit us and give us an opportunity of hearing some of your excellent papers. Although you have seen some experiments, they probably convey very little idea of the time that they necessitate in the way of preparation. If you had seen Mr. Stansbie, for weeks past, as I have, with his apron and chisel chipping out various materials, and melting things in crucibles, &c, so as to try to get these experiments into successful shape, you would then have some idea of the amount of preparation involved by these demonstrations. Besides, he has read up what everybody else has done, and he has been very careful to bring before you, in his paper, the chief researches of the various authorities on the subject. So that I should like to add my thanks to Mr. Stansbie for all he has done previously as well as this evening. The apparatus you see on the table is his own designing and his own manufacture. Everything is of a simple character, but, as you see, it has been most effective, and I may also say that he has been admirably supported by his colleagues and assistants connected with the laboratory. I think we have all learned to-night an immense amount of information as to the development of this subject. We have read of works—some of you may have visited such works—where electric smelting has been introduced. There is no doubt a great future for it, and I believe that in time to come the best steel will be made by electrical methods. There seems to me to be great hope of this method of making steel as compared with the lengthy and complicated processes of cementation and melting in crucibles. Crucible steel making involves considerable expense, and the steel fetches a high price. But we can produce such steel in the electric furnace in a very short time, and probably the gaining in time may compensate for any increased cost. What we want is for people round here, and especially our young men, to be instructed in the principles of metallurgy, and particularly in this branch of the subject. If you were to make representations to our committee, a class might be started here, or perhaps in your own district. It would involve a considerable sum of money, but it would be a good thing. We don't want to make any profit out of this work. We have the extreme

pleasure of giving, and the more we give the happier we are. Now just one word more. It is frequently said that we are simply theoretical men and that we know nothing about the practical side. If any of you have that idea, I can assure you it is entirely an erroneous one, for although we may not be able to go into a works and light the blast furnace or wield a sledge hammer, yet we can very frequently tell other people how to do it. That is a very common experience with us. People come to us when in difficulties and ask us questions about their trades. Or they say, "I want to do this in a cheaper way than previously, and I want you to tell me exactly how to do it." They come to us in that way and we do our best for them; and if any of you will take advantage of the facilities we offer—by sending your young men to us as students for instance—we will try to give them every possible information. Only a week or two ago a student came to our metal-colouring class and paid 5s. for the whole year; and the week after, he came from his firm with a request that we should tell him how to put a black-bronze coating on to a certain article, the same as was done by foreign makers. This we did, and he came next week and asked us to give him information as to putting on another shade, and this also we did. No greater reward, as teachers, can come to us than that a man should be able to say he has made a fortune through the information we have given him. If the Institute could make it convenient to hold some of its meetings in Birmingham instead of at Dudley, I believe they would find the committee always willing to give assistance.

THE PRESIDENT: It is now my duty to propose that the best thanks of the Institute be tendered to the Committee for the use of the room and also that a hearty vote of thanks be accorded to Mr. Stansbie for his very instructive paper.

Mr. HASKEW: I beg to second the vote of thanks, and in doing so I should like to endorse what Mr. Hiorns has said with reference to very practical work being done at the Technical School here. Five years ago I went on a visit of investigation to America for a big Birmingham firm. Well, although you can get drawings and plans you cannot always get your furnace building materials, &c., in England the same as in America. We had very great difficulty in getting a suitable bottom for a tube welding furnace, and one of the means I took to get the right thing was to come here and go through a number of experiments, and I must say they very largely assisted us in getting what was required. At the same time, while in America, I saw the furnace which Professor Turner has referred to for making carborundum, and I brought away a large piece of that material. The furnaces are filled with sawdust, common salt, and coke dust. The original experiments were, I believe, carried out with the idea of making diamonds. The material used now crystallises out into something like a diamond, and in colour it travels through beautiful shades of blue and purple and red, according

to its position in the furnace. With reference to the power necessary to generate electricity, water power is the best if it can be obtained. When I went to Niagara Falls, I found the place practically a large manufacturing town. The Pittsburg Reduction Company have a large works there for making aluminium, and I tried when there last year to get through, but could not get permission. I have much pleasure in seconding the vote of thanks.

The resolution was put and carried with acclamation.

Mr. STANSBIE: I am very much obliged to you for what you have said about my efforts to-night. I have tried to give you a general idea of the principles utilised in electric smelting. I have not read a paper. I have simply tried to bring the experiments before you, but I hope you will all read the paper itself, and derive as much benefit from it as you can. With regard to ferro-silicon, I should like to point out that Moissan has proved some rather important points about some of these re-actions, and he has shown that in order to get silicon, it is necessary to so arrange the furnace that the reduced silicon shall be brought out of the zone of highest temperature before it has time to unite with carbon. This is because silicon carbide is so readily formed at extremely high temperatures that it is difficult to get satisfactory results unless the silicon is drawn away from the furnace before the carbide has an opportunity of forming. The disintegration of 50 per cent. ferro-silicon mentioned by Mr. Hall is well known to the smelters, and it seems probable that not only the 50 per cent, but also the richer and poorer alloys are similarly affected to a smaller extent. Many samples, however, show very little signs of disintegration even after standing for long periods, and Mr. Watson Gray is of the same opinion as Professor Turner that the high percentage alloys do not disintegrate. Authorities have not yet arrived at any definite conclusion as to the cause of the disintegration, but it may be due to the escape of occluded gas in a moist atmosphere. I am very much obliged for the attention you have given me, and I hope I shall have the pleasure of seeing some of you again.

Before leaving the lecture room, many members of the Institute inspected the apparatus and specimens.

The Third Meeting of the Session was held at the Institute, Dudley, on Saturday, 26th November, 1904.

THE PRESIDENT (Mr. H. B. TOY) presided.

The minutes of the previous Meeting were read, approved, and signed.

THE PRESIDENT referred to the loss the Institute had sustained by the death of Mr. H. Le Neve Foster (a Past President and member of Council), and moved that a letter of condolence and sympathy be sent to Mrs. Foster. This was unanimously agreed to.

Mr. W. Attwood was elected a member of the Institute.

THE PRESIDENT then introduced Mr. J. H. HAMILTON (Nottingham), who read the following paper:—

THE GAS ENGINE IN IRON AND STEEL WORKS.

By J. H. HAMILTON, B.Sc.

Within thirty years the internal combustion engine has risen from the ranks of a toy motor to a position of importance as a rival to the steam engine in its larger sizes.

It has almost displaced the latter in small sizes except in exceptional positions, and who that has watched its progress in the last ten years can doubt that it is destined not only to drive the small steam engine into narrower and narrower confines, but to supplant the largest sizes and be applied to uses where at present the supremacy of the steam engine seems well established.

In that decade we have witnessed on the one hand the great spread of the suction gas producer, which, in combination with a gas engine makes as simple a power producer as the simplest kind of steam engine and boiler, and works on one-third to one-twentieth of the fuel consumption. Also the enormous increase in the number of oil engines, following improvements which have brought them into line with the older branch of the family.

On the other hand we have witnessed the introduction of the gas-producing plant, which can turn ordinary cheap coal or slack into a most suitable gas for driving engines, and which is already made in sizes capable of supplying the largest amount of power that even present day requirements demand. Also the application of the waste gases from blast furnaces and coke ovens for direct use in the gas engine.

Concurrently with these applications the gas engine has advanced in efficiency and size, the ten years having brought units of more than ten-fold power.

The not less wonderful developments in the electrical industry have also had their influence on the advance of the internal combustion motor, and, while they undoubtedly stimulated the demand for larger units, have also placed within reach of steam users a method of subdivision and distribution of power which has given birth to the steam turbine and a further lease of life to steam power. The ease of subdivision and distribution of gas power with the highest economy would otherwise have left the internal combustion motor without a rival where subdivision was necessary.

But in compensation, electrical transmission has opened up new uses for the gas engine, which already supplies power for operating cranes and tramways, and when the electrification of main railway lines takes place, the last monopoly of the steam engine on land will be invaded. For although the internal combustion motor has nearly ousted the steam engine from the smaller locomobiles and enabled them to equal in speed the most powerful members of the family, and has at least got a footing on the slow traction engine, it is hardly likely that the motor car will grow into a 1,500 h.p. locomotive, but rather that the work of the latter will be done by stationary engines using cheap fuel, which not only will give energy in return at a three or four-fold rate but also yield valuable by-products.

The destiny of the internal combustion engine is then an imperial one and justifies its claim on your attention; but we have here rather to consider what has already been achieved, and the solidity of the foundations on which its future will be built, than to forecast that future, though the progress made so far warrants us in saying that the process of evolution which has begun will continue, and that if it has even now solid advantages over its rivals these will be increased and obtain wider recognition.

It will therefore be in order to briefly consider the already established advantages of the internal combustion engine. These are :—

1st. Economy in the consumption of fuel.

2nd Convenience in the distribution of gas as compared to steam.

3rd Small supply of water required.

4th Boiler explosion risks done away with.

5th Ability to meet sudden demands for power by storage of gas.

6th The recovery of by-products in the process of gas making.

7th The greater simplicity of a gas power plant than of a modern fully equipped steam plant.

8th And last, but by no mean least, the direct utilisation of blast furnace, coke oven, and other gases, which are themselves by-products in other manufactures, in the gas engine without the intervention of the steam boiler.

In this latter application the economy is most marked, because the loss in turning the heat of combustion of the gas into heat in steam is avoided; but even when gas has to be generated for use in the engine, the following considerations would lead to the conclusion that the loss in the gas producer is less than that in the steam boiler.

(A) In the gas producer the fire is completely enclosed in non-conducting material and is better secured against radiation and conduction losses than the boiler fire.

(B) The combustion is of necessity economical, there being no production of smoke nor excess of air, as the latter is supplied in measured quantity and if in excess will affect the quality of the gas in such a way that a remedy must be applied.

(C) The heat in the outgoing gases can be largely turned to useful account in heating the ingoing vapour and air, and in raising this vapour.

The steam boiler combined with an economiser can show a similar advantage to the last, and by very careful installation and working can also compete with the producer as regards (A) and (B), and thus it results that the most economical boiler is as efficient as the most economical gas producer, but in daily practice the advantage will be on the side of the gas producer.

The maximum efficiency of each is about 85 per cent., but for every-day work the steam boiler will not average more than 60 per cent. to 65 per cent., and the gas producer 65 to 70 per cent.

Thus the Committee on Naval Boilers (1904) found that various water tube and cylindrical boilers had efficiencies from 59·2 to 82·3 per cent., these boilers being carefully worked as they were in competition with each other.

Mr. Hiller, in a very complete trial of an economical steam plant (1904) found the efficiency of the Lancashire boiler was from 59·89 to 62·7 per cent.

Mr. Humphrey (1900) found the efficiency of a Mond Gas producer was 84 per cent., but this did not include the raising of steam for use in the producer, and allowing for that the figure would be from 72 to 75 per cent.

The steam for this purpose is, however, now frequently obtained from the waste heat in the gas engine exhaust, but this saving should be credited to the engine rather than to the producer. It is analogous to the heating of feed water by the steam engine exhaust.

The scaling up of boilers, deposit of soot on conducting surfaces, blowing out, etc., considerably reduce their efficiency, and there are no corresponding sources of loss in the gas producer. When boiler tests are made the boilers are in good condition, but it is not practicable to maintain them so in every-day work; and when it is considered what waste will result from excess of air and from the least carelessness in the management of the boiler fires, it is small wonder that every-day practice falls far short of test results.

Similar observations would apply to the transmission between the generator and the engine, for if conditions are favourable, that is if the boiler is very close to the engine, the pipes perfectly tight and thickly lagged, there is little loss; but if, as usual in practice, the engine is

some distance away, the pipes not perfectly lagged and all the joints not perfectly tight, there is a loss which is not negligible. On the other hand, the great ease of making pipes tight at the low pressure at which gas is conveyed and the absence of expansion and contraction, and of course of loss of heat, makes the loss in gas transmission negligible in all cases.

But the greatest economy is in the gas engine itself, which, as will be seen from the extracts from published tests given below, exceeds in thermal efficiency the best figures for the steam engine by about 65 per cent.

THE GAS ENGINE.

Type and size of Engine.	Kind of Gas.	Cubic feet of gas per I.H.P. hour.	Consumption of heat in B.T.U. per I.H.P. hour.	Thermal efficiency per cent.	Experimenter.
"Premier" 500 H.P.	Mond	48·14	6,740	37·76	H. A. Humphrey
"Crossley" 400 „	„	58·1	8,125	31·2	„
"Cockerill" 600 „	Blast furnace	82·39	8,470	30·5	Prof. Hubert

THE STEAM ENGINE.

Type and size of Engine.	Superheat in degrees F.	Pounds of Steam per I.H.P. hour.	Consumption of heat in B.T.U. per I.H.P. hour.	Thermal efficiency per cent.	Authority for figures.
"Compound" 258 H.P.	295	8·97	11,100	23	Longridge
"Compound" 5000 „	0	14	16,240	16·7	Maker's guarantee
"Compound" 1000 „	99·9	11·1	13,922	18·28	Hiller

If the maximum efficiency of the gas producer or boiler be multiplied by that of the respective engines, we shall get the highest economy which has so far resulted from the development of each system.

The gas power figure is :—

·377 × ·85 = ·32 = 0·57lbs, of coal per I.H.P. hour.

and steam power :—

·23 × ·85 = ·1955 = 0·93lbs „ „

It need hardly be said that these are not everyday results, and indeed the fortunate combination of the highest efficiency gas producer or boiler and the highest efficiency engine probably never occurred in practice, as the tests of combined plants showing the consumption of coal per H.P. hour are higher than the above figures.

In a quite moderate-sized gas power plant the consumption of anthracite coal is frequently as low as 0·75lb. per I.H.P. hour, and in larger plants working on bituminous coal this figure can also be reached, the thermal efficiency of the power production being 24 per cent. in the latter case.

Against this we may place the very good result obtained by Professor Ewing from a Schmidt Superheated Steam Plant, viz. :—

1·41lbs. of coal per per I.H.P. hour,

corresponding to a thermal efficiency of—13 per cent., and the result obtained by Mr. Hiller in the plant above referred to, viz. :—

1·44lbs. of coal per I.H.P. hour,

corresponding to a thermal efficiency of 13·53 per cent.

Though the gas power plant shows a marked economy when contrasted with the most up-to-date steam plant furnished with the complex aids to economy which are necessary to secure such figures as given above, it presents still greater advantages when gas is found ready made, and of a quality which can be used in the gas engine like Blast Furnace Gas and Coke Oven Gas.

As we have seen, the boiler fired with solid fuel has an efficiency which may average 60 to 65 per cent., and this, by the use of an economiser, may be increased to 70 or 75 per cent.; but when fired by blast furnace gas the efficiency appears to be less, and considering the conditions of daily work, it may be taken that its efficiency will not average more than 60 per cent. when fired in this way.

The average compound or triple condensing steam engine requires 16lbs. of saturated steam per H.P. hour at 150lbs. pressure, and therefore has an efficiency of 13·8 per cent., and if this be multiplied by the boiler efficiency (·60) the product will be 8·28 per cent. heat turned into work, as against 30 per cent. which the average gas engine would utilise.

The figures obtained from experience on the continent show a greater difference, namely—a consumption of four to five times as much gas for the production of a given power by the steam plant, which is, no doubt, due to the fact that the steam engines displaced by the gas engines use more than 16lbs. of steam per H.P. hour, and that the boilers have an efficiency of less than 60 per cent.

Though the boiler and its accessories are saved, the gas plant involves the use of cleaning apparatus, especially in the case of blast furnace gas, and the general practice now tends to the adoption of the system known as the dynamic, which consists in giving the gas a rapid whirling motion in contact with water spray, the commonest way of doing this being by passing the gas through a centrifugal fan and allowing a stream of water to flow into the fan at the same time.

Settling vessels fitted with baffle plates are frequently used to separate the bulk of the dust before the gas goes to the fan, but this cannot separate the light and impalpable dust which is so fine that it will get carried by the slowest flowing gas, and for great distances.

Indeed, it may be necessary to use two or three fans and pass the gas through them in series, as it is good policy to clean the gas as thoroughly as possible.

The dynamic system of cleaning absorbs about 1 to 3 per cent. of the power furnished by the cleaned gases, so to make a correct comparison with a steam plant the gas engine must be debited with this. That is to say, if 3 per cent. is used, the thermal efficiency would be reduced from, say—

$$30 \text{ per cent. to } \frac{30}{100} - \frac{30}{100} \times \frac{3}{100} = \frac{29{\cdot}1}{100}$$

a reduction of 0·9 per cent., which is much less than the difference between one gas engine and another.

The great bulk of existing steam engines in iron and steel works are not so efficient as the case assumed above, viz.:—A consumption of 16lbs. of steam per H P. hour; indeed, old engines use more than twiee that amount, and even a fairly good engine uses 20lbs., so the economy in gas effected by changing from existing steam engines to gas engines will be 5 to 1 where the steam engines are economical, and about 9 to 1 where old engines are in use.

The great possibilities in this direction were perceived perhaps more generally on the continent than here, altnough Mr. B. H Thwaite had demonstrated in this country that blast furnace gas could be used in gas engines even before it had begun to be applied abroad.

But some English ironmasters turned their attention to this subject in the early days, and it must be a gratification to you to know that Staffordshire enterprise was represented in the new development, since Messrs. A. Hickman, Ltd., of Bilston, were about the first firm in

England to make a move towards installing a large engine. They were certainly the first to encourage home manufacturers to emulate foreign ones by placing an order with an English firm for a large blowing engine, and have followed that policy in subsequent additions to their gas engine plant.

Messrs. Cochrane, of Middlesborough, ordered their first engine abroad, but Messrs. Cochrane, of Woodside, have English engines worked by Mond Gas.

Gas engines now in use in iron and steel works are divided into two main classes known as the 4-stroke and 2-stroke cycles, for all gas engines now act on the principle of the introduction of a mixture of gas and air into the cylinder, its compression by the return motion of the piston aud its ignition at constant volume, and the difference between the two types arises from the way in which the charge is introduced.

The 4-stroke engine is the simplest, as its piston acts as a pump, sucking in the charge of gas and air on one of its outward strokes, compressing it on the return stroke, expanding after ignition on the next out stroke, and exhausting on the 4th stroke, which thus completes the cycle.

In the 2-stroke engine the suction and exhaust stroke are eliminated, or rather transferred to pumps which draw in gas and air and force them separately, or together, into the motor cylinder, expelling the products of the previous combustion. Thus the suction stroke of the pumps corresponds to the suction stroke of the 4-stroke cycle, and the delivery stroke of the pumps to the exhaust stroke.

In large engine practice it is absolutely necessary to have separate pumps for the gas and air, and thus the 2-stroke engine becomes more complicated than the 4-stroke, but on the other hand there are twice as many impulses per revolution. To reduce the number of working parts, and provide the free exhaust which is necessary in order that the new charge may be introduced in the very short time available for that purpose, it is usual to allow the piston to overrun ports in the motor cylinder, a construction which is certainly one of the weak points of the 2-stroke type.

There is also a loss of power in driving the pumps, which must work at considerable pressure in order to force the charge into the motor cylinder in the short time which elapses after the pressure has dropped nearly to atmospheric pressure, and before the ports are closed by the return motion of the piston. This and other sources of loss render the 2-stroke engine less economical than the 4-stroke type. Nevertheless, this type has been used extensively in Germany, and suffers less in comparison with the 4-stroke engine when using blast furnace gas, which is cheap and not so liable to cause premature ignitions as are the richer gases.

The large engines made in this country and now in use in iron and steel works are as follow :—

FOUR-STROKE TYPE.

"Crossley," by Crossley Bros., Ltd.
"Premier," by The Premier Gas Engine Co, Ltd.
"Cockerill," by Richardsons, Westgarth and Co., Ltd.

TWO-STROKE TYPE.

"Körting, by Mather and Platt, Ltd.
"Oechelhauser" by W. Beardmore and Co.

The first two have been developed in this country and are the only English designs made in large sizes, while the last three are of continental origin.

The Premier engine differs from the other 4-stroke cycle motors in that it is of the positive scavenger type, which means that the products of combustion left in the clearance or compression space of the ordinary 4-stroke engine are in this type swept out and replaced by air.

The larger sizes of the Crossley and Premier are made with two or more cylinders, and indeed the largest sizes of every make have multiple cylinders; but the Cockerill, Körting, and Oechelhauser are made in large sizes with a single cylinder.

Of these, the Cockerill has been built with the largest cylinder that has yet been used in gas engines, viz., 51in. diameter; but the Körting engine although not made of such large diameter runs it close in the matter of power developed in one cylinder, this being due to the fact that in addition to the increased number of explosions obtained in the two-stroke cycle, it is also double acting.

The Cockerill engine is now also made double acting, and two double acting cylinders in tandem, each working on the four-stroke cycle, give two impulses per revolution like the Körting engine. This double-acting tandem four-stroke engine has obtained some favour on the continent.

It may be noted here that probably the first double-acting engine and double-acting tandem engine of the four-stroke type were English designs made by Messrs. Dick, Kerr and Co., about 1889 to 1890, and were very similar to the engines now made on the continent.

But one of the greatest troubles in those engines arose from the fact that neither piston rod nor pistons were water cooled, which is almost the universal practice now, and, of course, this constitutes a material difference.

The water cooling of exhaust valves and pistons was first developed in this country in the Premier gas engine, which had water cooled exhaust valves in 1895 and pistons in 1898.

The author does not know when the system was first introduced on the Continent, but it was probably about the same time or a little later.

It was prophesied when he began to put water cooled pistons in the Premier engine that the thermal efficiency would be low, that the water supply might fail and the piston expand and seize in the cylinder; but these things have not come to pass, and a Premier engine with water cooled pistons holds the record for thermal efficiency, and a piston has never jammed in its cylinder from a failure in the water service.

There have been difficulties to overcome in circulating the water through a piston moving at a high speed, but the problem may be considered to be solved now, and water cooled piston rods have been in successful use for some years.

Messrs. Crossley Bros. have avoided the use of piston rods in two cylinder engines by the obvious expedient of placing two simple single-acting engines on opposite sides of, and having their pistons coupled to, the one crank.

This has the advantage of dispensing with a piston rod, but the disadvantage of an irregularity in the recurrence of impulses, for it will be seen that a forward impulse is immediately followed by a backward impulse, and then that there is an interval of two strokes without an impulse. Our first slide shows an engine of this type. This *v's a vis* design, as it is termed, is also used by the Stockport Gas Engine Co., though they have not built them in such large sizes as Messrs. Crossley; but the Deutz Co., or German Otto Co, have till recently built these engines in large sizes, as some of you may have seen at the Düsseldorf Exhibition.

The earlier Premier engines were also designed to avoid the use of piston rods, as will be seen from our second slide representing a 600 i.h.p. engine, one of which is now in use for driving rolling mills at Messrs. Monks, Hall and Co.'s works at Warrington.

In this design the motor cylinders are in tandem, but the place of the piston rod is taken by two side rods which connect the crosshead attached to the back piston to the enlarged end of the front piston. The side rods pass outside the front cylinder and the large end of the differential piston acts as the scavenger pump.

The scavenging arrangement may be made clearer by a reference to illustration No. 3, which represents a section through a single cylinder Premier Positive Scavenger engine from which the tandem engine was developed.

It will be seen that on the back stroke, air which has been drawn into the space between the large and small ends of the piston will be compressed, being retained by the valves which admitted it, and that when towards the end of the stroke the admission valve of the motor cylinder is opened by a cam the air will flow through the combustion chamber,

sweeping out the hot products of combustion, and leaving this space filled with comparatively cool air.

In the single cylinder engine this action takes place only once in two revolutions, the air being simply compressed and expanded again on the other revolution, but in the tandem engine the scavenging takes place alternately in each cylinder and therefore is repeated at every back stroke.

The reciprocating parts of this tandem engine were however too heavy to permit of the high rotative speeds desired by dynamo makers, and the confidence engendered by the success of the piston-cooling arrangement on Premier engines led to the adoption of a piston rod design which, while retaining the advantages ot scavenging, is very suitable for direct coupling to dynamos.

It will be seen from the section of this engine, in illustration No. 4. that the scavenger pump is now a separate piece and is placed in an inclined position above the front cylinder, but otherwise the scavenging arrangement is the same as in the older engines.

The water for cooling the piston rod and pistons is introduced between the cylinders and consists of swinging links with packed trunnion joints at the pivotted points. The inertia of the water is made use of to insure a proper distribution to both pistons. The gas admission valve is of the slide type and designed to produce a perfect mixing of the air and gas going to the cylinder, which is a factor in economical working.

It will be seen that the admission and exhaust valves are placed in the cover with their axes parallel to the centre line of the cylinder, a construction which avoids pockets or irregularity of contour in the combustion chamber, which have always a detrimental effect.

The method of operating these valves is worthy of notice, and is illustrated in our No. 5 slide, which shows the grooved cams which give motion through rollers and levers to the valves.

These grooved cams give a movement in both directions, and thus the closing of the valves is effected in a positive manner, as well as the opening, and does not depend upon springs, contrary to the usual practice.

The governor will be seen at the crank end, it being driven directly from the crankshaft, a construction which not only allows of a high speed, but gives a uniform drive free from the small jerks which occur in the motion when derived from that of the shaft which carries the cams.

All large Premier engines are fitted with electric ignition in duplicate, and so arranged that one pair of sparking points may be withdrawn for cleaning without stopping the engine.

Illustration No. 6 shows the other side of this engine, and gives a good idea of its general appearance. Engines of this type are now working on Mond gas, blast furnace gas, and coke oven gas.

Illustration No. 7 represents an installation of two Cockerill single cylinder engines working on coke oven gas, near Leeds. They are of 250 H.P. each and drive dynamos by belts. It will be seen that they have single web cranks and overhung crankpins, an unusual design for gas engines, although common in steam engines. Otherwise these engines follow standard practice, being of the ordinary 4-stroke cycle type.

Illustration No. 8 shows a portion of an installation of 250 h.p. Premier Single-cylinder Engines at the works of Messrs. Bayliss, Jones and Bayliss, Wolverhampton, In this case it will be seen that the dynamos are direct coupled, the speed being 150 r.p.m.

These are single-cylinder Positive scavenger engines, and are fitted with governor gear for varying the strength of the mixture according to the load. These continuous-current direct coupled sets run satisfactorily in parallel.

Illustration No. 9 shows the same engine, but from the opposite side, installed in this case at the Woodside Iron Works of Messrs. Cochrane and Co., near Dudley.

Illustration No. 10 shows a 700 h.p. Körting engine coupled direct to a dynamo in the same way. This view does not show the gas and air pumps, which are on the far side, but it gives a good view of the motor cylinder and the gear for operating the inlet valves on the motor cylinder, and the ignition which is of the magnetio electric type. The inlet valves will be seen at each end and above the cylinder, and the tail end of the piston rod appears through the stuffing box at the back of the cylinder.

The gas and air pumps are driven from a pin in a disc keyed on the end of the shaft.

The belt round the middle of the cylinder is an enlargement of the water jacket space to accommodate the exhaust belt inside.

As mentioned above, this engine is of the two-stroke type and double acting, and therefore gives two impulses per revolution, but the advantage thus gained is neutralised to some extent by the lower angular velocity which working conditions impose upon this cycle.

The same number of impulses, viz., two per revolution, requires two double acting, or four single acting, cylinders in the four-stroke type, and an example of the former is shown in illustration No. 11, which represents a Cockerill Double-acting Tandem Engine.

It will be seen that, contrary to this firm's earlier design, the admission valves are placed above the cylinders, while the exhaust are, as usual,

below. This construction first appeared in the Premier engine, and has been followed rather extensively in other designs.

A double-acting engine of this type is necessarily very long and not suitable for a high angular velocity, but of course the two impulses per revolution makes for steady driving.

All double-acting engines are less accessible for cleaning, etc., than the single-acting type.

All the above engines are suitable for general work or driving dynamos, the latter application greatly predominating, and we may now turn to some special applications of most interest to iron and steel makers.

Illustration No. 12 is a ground plan of the rolling mills driven by a 600 h p. Premier engine at Messrs. Monks, Hall and Co.'s works, Warrington. It will be seen that one train of rolls is coupled direct to the engine shaft, and another driven at a higher speed by ropes.

These mills roll bars, the direct coupled ones doing the first operations, and the rope driven reducing them to small sizes.

The billets are heated in a furnace fired with the Mond gas, which also drives the engine.

As the mills are not reversing ones the case does not present special difficulties, and a gas engine is specially suitable for this work, owing to its economy when working with an intermittent load.

But the most important application of power in connection with iron works is the blowing engine, and we find that the gas-driven blowing engine has reached a fair stage of development and has been constructed in large units. This adaptation involved some departure from steam engine practice, as the horizontal form is decidedly the best type for large gas engines, so horizontal cylinders both for the motor and the blowing part predominate; but some engines have been made with horizontal motor cylinders and vertical blowing cylinders, a type which, well designed, is capable of very good results.

Another departure from steam engine practice occurs in connection with the blowing cylinder valves, for the gas engine must run faster than steam blowing engines usually do, unless, indeed, it is to be very large and unwieldly for its power. The old type beat valves, common on steam engines, are not suitable for this higher speed. Indeed, beat valves are only admissible if the lift is small, and that involves either throttling the passages or giving a very ample length of "coast line" as we might term the other factor of the passage area. A long "coast line" means greater risk of leakage and generally more clearance, and difficulty in finding room for the valves without having excessive clearance.

Premier blowing cylinders are fitted with grid slide valves in the cylinder covers and positively operated by cams. These valves give a very large and direct passage, and the loss of pressure in passing the valves is consequently very low, an important matter when the large volume of air dealt with is considered. The clearance is also very small.

Messrs. Richardson, Westgarth and Co.'s recent practice is to use similar valves, but the delivery valve is opened by the pressure of the air on a piston attached to the valve and closed positively by the action of eccentrics.

Illustration No. 13 shows one of these engines in which the blowing cylinder is fitted with such valves.

In this, as in all the Cockerill blowing engines, the blowing piston is connected to the gas motor piston by means of a piston rod which has a coupling and guide between the two cylinders.

It will be seen that there is one single acting motor cylinder, but these engines are also built with two such cylinders, and also with double-acting cylinders.

All the valves of the motor cylinder are below it, which is the original Cockerill, or rather Delamere Debouttéville, practice.

Illustration No. 14 represents a Premier blowing engine at Messrs. A. Hickman's works, and it will be seen that the blowing cylinder is coupled up in a similar manner to the above; but in this case there are two motor cylinders, which give an impulse per revolution and conduce to smooth and steady running.

Illustration No. 15 is another view of the same engine showing the arrangement of valves in the end of the blowing cylinder, which are of the grid type, positively moved by grooved cams fixed on the extension of the shaft which operates the motor cylinder valves

Another feature of interest on this engine is the scavenging arrangement.

For this purpose air is taken from the back end of the blowing cylinder by means of the pipe, shown above the engine, which also conveys the air required for combustion. The admission valve of that motor cylinder which happens to be making its exhaust stroke is opened towards the end of the stroke, and allows some of the air which is compressed in the blowing cylinder to flow through the clearance space and drive out the products of combustion. The amount of air used for this purpose is very small in proportion to discharge of the blowing cylinder.

This is, perhaps, the most powerful gas blowing engine in England, as it has a good margin of power when driving its 72in. blowing piston.

Illustration No. 16 shows another way of coupling the blowing cylinder, and represents a single cylinder Premier engine for furnishing blast to cupolas at Messrs. Cochrane and Co's Ironworks, Woodside.

In this case the blowing piston is driven from a pin in a disc keyed on the outer end of the crankshaft.

The blowing cylinder valves are of the same type as those in the larger engine described above, and appear plainly in the illustration.

Time will not permit of the citation of further examples, although many could be added, to show that the gas engine has already obtained a good footing in iron and steel works.

Difficulties there have been, as in every new departure, and if some still remain, they are being conquered one by one, and the gap between the ideal and the real is being narrowed.

For iron and steel makers there is the abiding fact that the gas engine uses their blast furnace gas direct, and for a given amount furnishes many times as much energy as the steam engine, and that its complete adoption in their works will render it unnecessary to consume fuel anywhere except in the blast furnaces, and furnish all the increasing power which the newer systems of working demand.

THE PRESIDENT announced telegrams of apology from Professor Turner, Mr. J. W. Hall, and others.

THE DISCUSSION.

THE PRESIDENT: This is, no doubt, the age of progress, and whether by force of circumstances or otherwise we are all seeking a less expensive motive power, and as gas engines are at the present moment much in favour, the subject for discussion this evening is a very interesting one. For some considerable time the officials engaged in many industries have been watching the development of gas engines, and most of them are now of opinion that these engines, working in direct connection with suction gas producers, will, at least to some extent, supply a much-needed want, not only in this particular district but in all our great iron and steel centres, and will greatly influence many other branches of business in the future. The paper brings before us valuable practical and scientific details, and I hope the members will freely enter into the discussion. There are many other first-class makers of gas engines whose names do not appear in the paper, and as some of these makers are represented here to-night we should like to hear them describe the vertical type of gas engines. I have had the pleasure of seeing many of the engines described by Mr. Hamilton this evening, also those

working at Seraing, made by Messrs. Cockerill, and the eight engines erected at Cargo Fleet, made by Messrs. Westgarth, Richardson, and Co., each engine capable of developing 700 to 800 B.H.P. Messrs. Beardmore, of Scotland, are driving a light plate mill with a gas engine using producer gas. Messrs. Monks, Hall, and Co., as stated by Mr. Hamilton, have employed gas engines for driving rolling mills for a considerable number of years. These facts, therefore, provide conclusive evidence that gas engines will be largely employed in the future, and that we may expect very great economy accruing as the influence of this development. The PRESIDENT then called upon Mr. Brooks.

Mr. W. BROOKS: It has afforded me considerable satisfaction to listen to Mr. Hamilton's exhaustive and capable paper. I doubt whether the Institute is as fully aware as it should be of Mr. Hamilton's position in the gas engine world. In that gentleman we have an engineer who has taken a very prominent part indeed in bringing the invention, particularly in the matter of large sizes, to its present perfection. Like the automobile, the gas engine has certainly come to stay. Of this I make not the least doubt. Personally, I have had experience with it at the works of Messrs. Cochrane, of Woodside, near Dudley, and I am pleased to testify that the Premier engines we have down there have given us the amplest reasons for satisfaction. Our experience has been altogether favourable and such that we can confidently recommend this type of motor to other iron and steel making establishments. The gas engine works remarkably regularly, and if properly tended, gives the minimum of what you would call trouble. So gratified indeed are we with its behaviour, that we are able to pronounce it an ideal engine for ironworks purposes. During the twelve months ending October of this year, I have taken careful note of the number of times that the engine that is coupled-up to the dynamo for electric power purposes has been started, and under what circumstances. I find that altogether we started 320 times. Of this total 312 times were started punctually, and we were only late eight times. Even of those eight, the late start was not in every instance due to defects in the engine. These figures have satisfied me that in respect of punctuality of starting and regularity of running, we have come to as near perfection as possible—that is, that we have got the very best engine for the work. I do not think that any iron or steel works' management can do better as concerns a supply of economical, clean, and regular power, even for the heaviest of work, than lay down the gas engine. I am not ashamed to confess that I have been captured by it myself, and I believe it to be the ironworks engine of the future.

Mr. R. G. MERCER: It has been a very great pleasure to me to listen to such a very interesting paper as Mr. Hamilton has just given us, the more so as his illustrations were most instructive. Having had considerable experience in oil and gas engine design and manufacture, I am able to endorse very much that was said by Mr. Hamilton favourable

to the latter class of power producer. Particularly am I prepared to second his suggestions in the matter of lessened cost of running and maintenance contrasted with the steam engine. The saving in this regard is incontestable. But gratified as I am with much that Mr. Hamilton put down, being an Irishman I do not think I would be following the traditions of my country unless I brought forward a few grievances this evening. Happily, however, my initial grievance is a very trifling one, I refer to where the author deals with the relative powers of the gas and the steam engine. It will be found tabulated on page 51 and the comparisons are continued on page 52. Now, although as I have already stated, I am myself a convinced oil and gas engine man, yet I have more respect, shall I say compassion, left for the dear old steam engine, and being compassionate I feel that as little injustice as possible is steam's due. For its wide service in the past to manufacture and industry we should at least be grateful. Therefore it is that I should like to have heard Mr. Hamilton, in his comparisons of the relative merits of the gas engine and the steam engine, put everything down in brake horse-power, not indicated horse-power. I think that would have been fairer to steam. If I am going to put a gas engine down, the first thing I want to know, quite apart from the capital outlay, would be the consumption cost per B.H.P. per hour of that engine at, say half and full load, and the efficiencies at those loads. Consumption per I.H.P. would be no use to me ; on paper they look very nice, but I would prefer to have the figures showing what is will cost me per h.p. delivered at the shaft. Nominal horse-power is another phrase which may mean anything ; it may mean much or it may mean little, according to the mode of reckoning. We used to hear a good deal about nominal horse-power and it is not dead yet, but although I have studied the point for a good many years, I have never yet been able to arrive at a respectable conclusion concerning what is intended to be implied. Now I turn to my main grievance of to-night; we are all, I think, pretty well convinced by now that the horizontal steam engine has been superseded by the vertical type, except for special work. The transition, or I may more exactly describe it by the word evolution, is very easily explained. It is to mechanics what in nature is recognised as the survival of the fittest. The high pressure vertical steam engine is much more economical, and calls for less maintenance and attention and less floor space. The revolution which has been worked in the introduction of the high speed vertical motor in the old realm of steam I believe to be only typical of the change that we shall see brought about in the progress and development of the gas engine. What, I should like, very respectfully not very pertinaciously, to ask Mr. Hamilton to-night, has the vertical multi-cylinder gas engine done that it finds no place in his paper? Why has he never even hinted at its existence? Has Mr. Hamilton no room for it? If he assumes that there is but one Richmond in the field, let me tell him he is mistaken. I speak for the

British Westinghouse Electric and Manufacturing Co., Limited, as I daresay many around me know, and I say that the vertical gas engine is the very latest development in gas engine practice, and the highest, and I am not speaking without experience. To imagine that in the horizontal form the power producer that we are discussing to-night has reached its goal is absolutely futile I will tell you why I think so; I will mention a few points which figure in the consideration. The horizontal motor, in the first place, takes up a much larger floor space than the vertical; this must be evident to all, and in many cases of installation space is a very valuable commodity. Next, take a three-cylinder single-acting vertical, or for large power a two-cylinder double-acting vertical gas engine, made, we will say for the sake of illustration, by the Westinghouse Company. In both these motors the cylinders are arranged vertically; this secures many great advantages. The engine is enclosed, and like a vertical steam engine splashes itself with oil; the pistons operate vertically, and consequently there is even wear all round the walls of the cylinder if there is any wear at all, whereas in the horizontal engine the big heavy piston is doing its level best to make the cylinder oval. In the three-cylinder engine the cranks are arranged at 120° to each other, thereby giving as uniform rotation as the highest class of vertical steam engines. Instead of one great big impulse you have three small ones per cycle of operations which, in addition to low speed variation, means longer life to the engine and less wear and tear all round. In the case of the engine being driven by suction plant, you only have three small steady sucks instead of one big suck; the draught through the gas generator is kept regular and steady and the incandescent fuel therein has not time to go dead. Then again, the exhaust is practically noiseless, being absolutely regular in action, and compares more to the exhaust of a steam engine than anything else. This is a very important point. We have at Walthamstow a battery of vertical gas engines of our make, aggregating 3,000 h.p., for supplying the electric trams with current, and you can imagine the row there would be if the exhaust was anything like as noisy as in the horizontal type. Well, gentlemen, I spoke just now of a vertical double-acting two-cylinder gas engine; the great advantage which accrues from this style of motor, for the production of electric power for instance, is that the dynamo can be placed directly between the two engines, that is right in the middle, the stress and strain is thereby distributed along the whole length of the shaft. In the same way, if the engine is required for belt or rope drive, the pulley is placed between the two engines. I trust that you will excuse my dwelling at such length on this interesting subject, but I should like to say in a word that I am persuaded from experience that the gas engine, as compared with the steam engine, is the real thing for the future in every iron and steel works no less than in engineering and machine shops, and in many other manufacturing establishments, and further, that the vertical gas engine is the very real

thing, and I don't say this because my company are not makers of the horizontal type, but because it is judgment formed after careful trial.

Mr. W. Moore: For the last few years I have been saturated with gas engine matters and practice. I have listened carefully to Mr. Mercer's remarks about vertical versus the horizontal gas engine. In some particulars, I sympathise with those remarks; I have been of much the same opinion as himself for some time past. But care must be taken with regard to size. I do not think that anything very conspicuous has been accomplished by the vertical engine of large sizes. I have not heard of any large installations of the vertical type. I hesitate to pronounce in favour of the vertical engine while men of Mr. Hamilton's ability in engineering matters cling to the horizontal engine. I question if the high position Mr. Hamilton occupies in the gas engine world is sufficiently recognised by this Institute. He is one of the few men in the kingdom who have thoroughly studied the gas engine from a scientific point, and when he expresses a preference it is for other men to be careful what they reply. Under these conditions any dogmatic pronouncement by me would be out of place. Still, in the matter of smaller sizes, I am inclined to think we can get a very good vertical gas engine.

Mr. W. Brooks enquired whether Mr. Hamilton was of opinion that for electric tramway purposes gas engines would afford a suitable generating power supply. The matter was one which had lately occupied the attention of the Dudley Corporation. It was then urged that gas engines were inapplicable to electric tramway working, particularly for driving uphill. His own opinion was contrary to this, and it would be an assistance to have the verdict of such an authority as the author.

Mr. Walter Macfarlane, F.I.C.: Coming immediately after gentlemen who have had practical experience of that description of power which we are discussing to-night, I fear my remarks must suffer by comparison. Nevertheless, I have followed, theoretically at least, somewhat closely the subject of gas engines, believing it to involve one of the most practical questions in twentieth century engineering where economy is aimed at. Mr. Brooks has given us the right direction of thought in his remark that "the gas engine has come to stay."

On page 53 of his paper Mr. Hamilton refers to the economy which may be effected in iron and steel works by an alteration from steam to gas engine power, and he remarks that "the great possibilities in this direction were perceived perhaps more generally on the Continent" than in this country. He then goes on to speak of the efforts of Mr. B. H. Thwaite in showing, before the principles had begun to be applied on the Continent, that blast-furnace gases could be applied with advantage to gas engine driving. Well, sir, we have good reason to admire the splendid work done by Mr. Thwaite. But we must remember that

the first gas engine run by blast-furnace gases was set going at the Wishaw works of the Glasgow Iron Co. while under the management of Mr. James Riley. Mr. Riley is also intimately identified with the utilisation of gases from coke ovens for power purposes.

A peculiarly fortunate circumstance—and one which has largely made for the success of the early experiments—was that the first iron-works' gas engine worked by blast-furnace gas was supplied with gas which had been thoroughly scrubbed for the recovery of the "chemicals" which it contained. The gas was thereby impoverished, but it was thoroughly freed from dust. That was unquestionably an important factor in securing the favourable results obtained at that time. In the matter of early Continental practice, too, it was no less happily in favour of the pioneers in the application of gas power to heavy iron and steel manufacture that the first gas engine installed in a Continental iron-works was fed by blast-furnace gas which had travelled a considerable distance before being used in the gas engine. Much of the blast-furnace dust—which is so hurtful in the cylinder if it gets there—must have subsided during the journey through the culverts. The initial success in North Britain and on the Continent induced confidence in the new installations, and, as all of us are aware, that confidence has gone on steadily extending and deepening on the Continent and in this country to the present time. Clever and bold as the Continental engineers are in handling this important matter (and they are deserving of hearty acknowledgment), I am fully persuaded that British enterprise and British engineers will travel side by side with them. Nay, more, the qualities which I have alluded to will keep England well to the front. And the contemplation of such papers as we have had placed before us to-night by a scientific engineer occupying a foremost position in the gas engine world strengthens that conviction.

Mr. Hamilton has mentioned the magnificent installation at Sir Alfred Hickman's works at Bilston, and very rightly he has spoken in high terms of what has been accomplished at those works. I am inclined to believe that at no other ironworks in the world is there a gas engine installation of equal power and merit. But as we are without authoritative information on this point, I should like an expression of opinion from the author before he goes.

I cannot sit down without expressing my most cordial appreciation of Mr. Hamilton's admirable paper.

THE PRESIDENT: In moving a vote of thanks to the author, I feel compelled to say that I am sorry that the figures figuring in the paper attempting to elucidate the comparitive merits of the gas engine for iron and steel works' practice are not such as we can conscientiously accept. In my opinion they do not allow us to make a fair and unbiassed comparison between the two types. A "Premier" 500 H.P. gas engine, for example, is contrasted with a 400 H P. "Crossley" gas engine, and

again with a 600 H.P. "Cockerill" gas engine. Then again, the comparisons between the gas and the steam engine seem to me to have been induced when the boilers were comparatively new and in a very good condition. I know this is nothing unusual, indeed it is common practice. None the less it has always seemed to me that these comparisons should be conducted when the boilers have had some work put upon them, and the plates have received a certain amount of lime deposit, such as we well know always occurs in actual working. For these reasons, I cannot feel that the figures given us by Mr. Hamilton in his valuable paper are of great service to us as iron and steel works' managers who may possibly come to adopt the gas engine for our mills. The representative of the British Westinghouse Company has expressed his preference for the results stated in brake horse power rather than in indicated horse power. I find myself at one with him in this. Results measured by I.H.P. are apt to be misleading. It should never be forgotten in making experiments such as these, that the friction of the engine or engines experimented with should be taken into account. In attempting to decipher the exact power of an engine, the energy given off at the shaft should be gauged. There is another matter I want to speak about, and here the makers rather than the investigators of gas engines are at fault. Gas engine makers, whether Continental or British are behind in this, that they have not yet standardized their machines. In buying an engine this circumstance operates very awkwardly. A would-be purchaser, for whatever purpose, whether for an ironworks or ought else, has to have all his wits about him if he is not be disappointed. I will illustrate my meaning. In negotiating for a gas engine you will soon learn that the different makers have different sizes for the same powers. There is no uniformity. Five different makers will quote you as many perhaps as five different sizes for developing one and the same power, and a difference even of 2in. to 3in. in the diameter of the cylinder will appear. Differences like these are most confusing, and, as I have said, in the present only partially informed condition of buyers in respect to exact gas engine capabilities are likely, if not very carefully watched, to be sometimes very misleading. As is now becoming the recognised practice in some departments of iron and steel manufacture, the gas engine makers should standardize their productions—say on a 20 H.P. basis, or some other ready basis equally acceptable to consumers. Whether in the case of say a "Premier," a "Crossley," a "Westinghouse," or any other admitted type of make, the exact H.P. given off in daily running should be the same in a similarly figured engine. One other word with our author. I think he should have given us the comparative cost of engines working from suction gas producer plant as against those not so provided. Mr. Hamilton, in the introduction to his admirable paper, rightly reminds us that during the last, say, ten years there has been a large extension of suction gas producers. But he gives us no

details of the special effects resulting at those works where this very valuable plant has been laid in. Now, I have myself inspected a great number of these plants at work, and, in the case of moderate installations, always with the best results. I am of opinion, from my experience, that these suction plants will be employed in still greater numbers in the future, owing to the satisfactory results already observed. I am referring now to their use in conjunction with the smaller gas engines. For larger powers they have been perhaps hardly so successful. Mr. Brooks has put a question to the author regarding the employment of gas engine power for electric tramway purposes. I entirely sympathise with the inquiry. I decline to admit the difficulties that I understand have been suggested in public. I see no sufficient reason why the power we have been investigating at this meeting should not prove just as acceptable when installed for public electric tramway service, as has been shown to-night that is at once capable and economical in our ironworks. The Dudley Corporation need have no fear in putting in gas engine plant for their new tramway requirements. I believe, too, that events of the next few years will show continuous progress in the adoption of electric driving power for a multitude of purposes, alike private and public.

Mr. WALTER SOMERS: I have much pleasure in seconding that the best thanks of this meeting be given to Mr. Hamilton for his paper. Nothwithstanding his facility with all matters affecting the gas engine, the paper must have taken him much time and, I have no doubt, some trouble in its preparation. The subject of gas engine employment for iron and steel works purposes is a practical one, and one that should receive attention from all of us, particularly at a trade period like the present. If any profit is to be made upon our output, added economy in the process of manufacture must unquestionably be our watchword. Papers such as we have listened to to-night are the more valuable when they are the contributions of men who have attained such distinction in their profession as Mr. Hamilton. If I may be permitted the witticism, Mr. Hamilton is a man who to-day admittedly occupies a premier position in gas engine circles. It is the wish of everyone here that in the future his success may be increasingly brilliant.

The vote of thanks having been put and passed:

Mr. HAMILTON: I thank you very much for the reception which you have given my paper and for your expression of goodwill towards myself. It has been a pleasure to me to come with this subject before an audience in this district, as Staffordshire has shown greater appreciation of the new source of power than other parts of the country, and when one has to urge the merits of a system not yet extensively adopted, the atmosphere of enterprise which has always distinguished Staffordshire makes the task easier. I was gratified to learn from Mr. Brooks' statement that the Premier engines at Messrs. Cochrane's Ironworks at

Woodside have been so regular in starting. As these engines are fitted with the single impulse explosion type starter, I think you will agree that the figures mentioned by Mr. Brooks are highly satisfactory and reflect great credit on those who have charge of the engines, as well as on the latter.

As a compatriot of Mr. Mercer I quite recognise his right to a grievance, but perhaps on investigation it will be found to have as little ground for its existence as candour compels me to acknowledge exists in the case of other natives of the soil. It is true that many makes of gas engines have not been mentioned in my paper, the reason which determined that an engine should be mentioned being its use in an iron or steel works. I daresay there are a number of small gas engines in use in such works, but neither in size or design do they call for any attention, being of a well-known make or mere copies of it. But I know of only one case of the use of a Westinghouse engine in an iron or steel works in this country, and about this engine I have not been able to get any particulars, or at least any authentic and suitable for publication, and so it comes that it was not included. I have information about all the other engines mentioned in my paper from actual use in iron or steel works and that is the reason why they are included.

Nevertheless, the question of horizontal against vertical engines is a a pertinent and interesting one. I do not admit Mr. Mercer's premises that the horizontal steam engine has been superseded by the vertical It is true that the development of electric generating direct coupled sets has brought the vertical engine into prominence, and this type offers special advantages for high speed short stroke enclosed crank engines, considerations of maximum economy taking second rank

But these advantages are not present in the same degree in the gas engine, and disadvantages not found in the steam engine exist in it.

Indeed, it would be nearer the truth to say about gas engines that the horizontal type has superseded the vertical, seeing that vertical gas engines were more extensively used many years ago than they are now, and several makers, and among them my firm, have given up the manufacture of vertical engines after a trial of their possibilities.

The main advantage of the vertical engine is the very apparent one of occupying less ground space, and the next, from a manufacturer's point of view, is a prejudice in favour of that type on the part of electrical engineers and others, engendered by the good results obtained with vertical steam engines, but in no sense warranted by the performance of the vertical gas engine. The former advantage must always secure a preference for the vertical type where space is so valuable as to overshadow the disadvantages which any expert can see pertain to the design that Mr. Mercer seems to think so perfect. What the future may bring I shall not prophesy, but replying to Mr. Mercer's challenge I say that at present the horizontal engine has advantages at every point save only in question of ground

space, and as the difference is not great in this, and generally of little importance in iron and steel works which are not usually placed in crowded cities, the horizontal engine is the type par excellence for such works.

Mr. Mercer says, in stating the advantage of the vertical engine, that there is even wear all round the cylinder, but that is not the case in the Westinghouse three-cylinder engine, because there is the lateral thrust of the connecting rod which amounts to far more than the weight of the piston, so that the vertical position does not prevent the cylinders of such engines wearing oval.

Then the splash lubrication which he describes and as exemplified in the above engine is radically wrong, and as a matter of fact engines oiled in this way consume much more oil and wear no better than the horizontal type. The question of multiple cylinder engines as against single cylinder ones is also one that admits of a good deal of discussion, but I believe that up to a certain size the single cylinder type is best, being much simpler and easier to look after, as well as more economical and more reliable. For instance, a leaky valve makes much more difference in the working of a small cylinder than in that of a large one, and there are many other little matters which give an advantage to the single cylinder type in everyday work. But devotion to the monocylindrical type can be carried too far, and then it means excessively heavy parts and an expensive engine to build. Therefore, in this, as in nearly every other problem of engineering, it is a matter of balancing advantages against disadvantages and calling in judgment founded on experience to decide where the line should be drawn.

Mr. Mercer's argument that a single cylinder engine would not work so well with a suction gas plant has not much weight, because the capacity of the pipes and cleaning apparatus of the gas plant is sufficient to form a reservoir which will prevent that "one big suck" from reaching the producer. The exhaust of any other engine can also be made almost noiseless, if the owner is willing to put up with the waste of water and corrosion in his exhaust pipes which the use of the wet method of silencing involves.

The Chairman, as well as Mr. Mercer, has spoken in favour of giving results in brake h.p. instead of indicated, and where it is possible to absorb and measure the power of the engine with a brake I agree with him. But this is not practicable in the case of the larger engines I have described unless at great cost, and when the consumption of steam and coal in the case of steam engines is given in terms of the I.H.P., I think it fairer in comparing gas engine results to also take the I.H.P.

In engines working with producer or blast furnace gas, the indicator cards are really more to be depended on than in the case of the steam engine, seeing that there is no trouble from condensation, and a good gas engine of large power has a mechanical efficiency of 87 per cent. to 90 per cent., which is little different from that of the steam engine.

I am aware that, for instance, in gas engines of the two cycle type the gross I.H.P. is greatly in excess of the nett I.H.P., which should, of course, be taken when comparing with steam engines; but my contention is that if all points are taken into account and a suitable indicator used, the I.H.P. is a very reliable way of measuring the power of a gas engine, and results so obtained are strictly comparable with those from the steam engine. I wish to thank Mr. Moore for his remarks, which show that he appreciates the difficulties which anyone has to face in making a new departure. It might be thought that the small gas engine being a success, all that is requisite in making a large one would be to enlarge the scale; but that is very far from being the case, as may be seen from the fate which overtook all attempts of this sort.

Indeed, we who began with small engines had much to learn, and something to unlearn, in the course of the solution of the large engine problem. There was no literature of any value on the subject, and apart from the fundamental science which must always be a help to workers in such a field, no assistance to be derived from books or papers. In fact, history has been repeating itself, and all who have helped to advance large gas engine practice have had to do so more or less by a system of trial and error. A good deal of trial in more than one sense, and a quantity of error depending on the soundness of judgment with which they chose their ends and means to accomplish them.

Mr. Brooks asked if gas engines would be suitable for driving dynamos in an electric tramway system. My opinion is that they would be eminently suitable for such a service. They are indeed being used for this purpose to some extent on the Continent, and as a gas engine takes an intermittent load in better style than a steam engine, sudden changes in the load would be no objection. Indeed, with a certain amount of storage capacity in the gas plant, a gas driven station would be better able to deal with rapid fluctuations in load as well as being more economical than a steam driven station.

In reply to Mr. Macfarlane, I believe his information that Wishaw was the first place in this country where blast furnace gas for driving a gas engine was tried is correct; but I think it was tried there at the instance of Mr. Thwaite. I agree with Mr. Macfarlane in thinking that the success attained at Wishaw was greatly due to the excellence of the gas, and that had a poorer and dirtier gas been met with in the first installation it would have militated against further progress. Also, that the first trials with blast furnace gas on the continent were likewise under exceptionally favourable conditions for the reasons he mentioned. As he says, we owe a great deal to the continental engineers who have done so much to carry the work of Lenoir, Langen, and Otto towards its perfect development.

Mr. Macfarlane asked whether the gas engine installation at Messrs. Alfred Hickman's works is not the largest in this country, and I think that taking the plants now at work this is the case, though the plant just installed at Cargo Fleet is undoubtedly larger, and when it gets to work will take first rank so far as the total power is concerned. The President suggests that in comparing the thermal efficiency of different engines the same sizes should be taken; but I would point out that careful trials are not sufficiently numerous to supply these data. Moreover, the difference in power between the three gas engines for which the figures were given, is not sufficient to account for any appreciable difference in economy. Theoretically, the engine with the largest cylinder should have given the best result, and therefore the Cockerill, which has a cylinder more than twice the capacity of either of the others, should have done best, but as will be seen it has the lowest efficiency. It also had a higher compression than the other engines, which again makes for economy, but the above advantages were more than neutralised by details of design. The sizes and types of steam engines were purposely chosen so as to be representative of a large range, and to show the best authenticated performances.

I quite agree with the President in his contention that a test more useful to users of power would be one made under every day conditions, after a plant had been working for a considerable time, and there is no doubt that such steam engine performances would be much worse than tests of new or specially prepared plant. Boilers with scale inside, and soot outside, would give a lower evaporation; steam leaks, and the various small sources of loss, which are stopped when a set trial is made, would reduce the engine efficiency. But these figures are not available, and all that we can do is to compare such as are available, that is to say, those for new plant, or for installations which have been prepared for testing.

In replying to Mr. Mercer, I have already spoken on the question of brake h.p., and I have only to add that I quite agree with the President that this is the power which concerns the buyer, though the well-advised one should also go into the question of the indicated H P., because without that he cannot arrive at the mechanical efficiency which is a very important matter, especially when working at low loads. But I do not agree with him in respect to his suggestion that dimensions should be standardized, which is in effect a proposal to return to the nominal H.P. that has so greatly puzzled Mr. Mercer, because the origin of nominal horse power, both in the steam engine and gas engine, was an endeavour to standardise engines so that all engines with the same size of cylinders should give the same power.

In the steam engine, the rise in pressures and speeds so increased the power that it became several times greater than that which had previously been obtained and which had been given the name of

nominal H.P., and so the latter ceased to represent the actual power, though the convenience of having a term to distinguish an engine by its cylinder dimenions kept it in use long after it bore any fixed relation to the actual power.

Exactly the same course of development has characterised the gas engine, becaues in the early days, when the slide admission and ignition valve were used, and the compression was 40lbs. per square inch or less, certain cylinder dimensions were found to give safely a certain brake H.P. in continuous work, and this was fixed as the power (nominal H.P.) corresponding to the cylinder dimensions. The increase in compressions and speeds, and certain improvements in design, however, soon enabled gas engine makers to obtain increased power, and then the nominal power in this case also ceased to represent the suitable working load.

The increase of power was accompanied by an improved thermal efficiency, since some of this increase represented heat utilised which formerly had been lost, and as the amount of this saving materially depends on the skill of the designer and the measure in which he is guided by the laws of thermodynamics, it happens that owing to skilful design, some engines give greater power and economy from a given size of cylinder than others, so that if the President's suggestion were adopted a premium would be put upon bad design, seeing that a well designed engine would command no higher price than a poorly designed one having the same size of cylinder, although capable of doing considerably more work.

The Fourth Meeting of the Session was held at the Institute, Dudley, on Saturday, December 17th, 1904.

THE PRESIDENT (Mr. H. B. TOY) presided.

The minutes of the previous Meeting were read, approved, and signed.

Messrs. Isaac Downing, Walter Gale, and J. P. Tilley were elected members of the Institute.

THE PRESIDENT, in introducing Major Trinham, said that gentleman had travelled from Scotland that day to read the paper.

MAJOR TRINHAM then read the following paper :—

THE GARRETT RE-HEATING FURNACE.

By J. S. TRINHAM.

A short time ago your President asked me to write, for the members of this Institute, a short account of my experience of the Garrett Re-heating Furnaces, describing the method of working them and the results obtained. Whilst fully appreciating the honour of the invitation, I did not readily accept of it, because the high standard of papers usually discussed at these and similar meetings caused me to doubt whether a paper on such a minor subject would prove interesting. Mr. Toy's assurance that anything concerning re-heating furnaces was always acceptable to the Staffordshire Iron and Steel Institute, determined me to comply with his request. In doing so I also took into account the fact that the discussion which usually follows is very often of more real worth than the paper itself. At the outset, let me make it quite clear, that I have no personal interest whatever in the Garrett patent, and anything I may say, for or against it, is the result of my own observation. The figures I shall put before you are taken from records made by a competent and reliable man who was specially detailed to carefully watch coal and furnace wastes of different types of furnaces, including the Garrett patent. These records were made with the object of ascertaining the real worth of the Garrett patent, as I had two furnaces of this type at work and was desirous of still further adopting them if the results proved satisfactory. After comparing the figures and carefully observing the furnaces myself, I felt justified in recommending my directors to alter all the re-heating furnaces to the Garrett type. This has already been done in one of the works under my charge and the furnaces at the other works will be altered at the end of the present month.

Given a green field, I would not risk saying that the Garrett furnace is the best possible furnace to put down, but I maintain it is better than the ordinary closed grate furnace with steam jets, and of course there is no comparison between it and the open grate furnace. There is also this in favour of the Garrett grate, it is easily and cheaply adapted. As you will see shortly, the whole secret lies in the grate, the remainder of the furnace being built to suit local conditions, &c. It is just the thing for manufacturers who feel their furnaces are in need of some improve-

ment, and who are either unwilling or unable to disturb practically the whole of their existing heating and boiler plant to put down, say Siemens Gas Regenerative Furnaces and separate boilers to raise steam at an enormous cost. Indeed, I am doubtful whether such furnaces are as economical as they are sometimes alleged to be. In the Journals of the West of Scotland Iron and Steel Institute you will find a very excellent and exhaustive paper by Mr. Fred Mills on "Re-heating Furnaces for Iron and Steel," in which he says, "Speaking generally, it is my belief "that it is unnecessary to gasify fuel if the temperature desired can be "obtained by burning the fuel in the furnace where the work is to be "done." As I am speaking to gentlemen who are almost entirely engaged in the manufactured iron trade and who must use horizontal re-heating furnaces on account of having to turn over the piles, I am sure they will agree with me that sufficient heat is obtained in the manner mentioned by Mr. Mills. Quoting again from the same paper, "Add to the fact that nothing is gained from a caloric point of view by "gasifying the fuel, the enormous loss by oxidation in the producer and "in the gas tubes, and also interest and depreciation on a very largely "increased first cost of both producer and furnace plant. It would "therefore appear that, given a reasonably good fuel, coal-fired furnaces "should meet all our requirements."

The author of the paper referred to quotes Ganôt the French scientist, as follows:—"A body, in burning, always produces the same quantity "of heat in reaching the same degree of oxidation, whether it attains "this at once, or only reaches it after passing through intermediate "stages. Thus a given weight of carbon gives out the same amount of "heat in burning directly to carbonic acid as if it were first changed "into carbonic oxide and then this were burnt into carbonic acid."

I trust you will excuse the somewhat lengthy extracts, but they appear to me to hit off the case so well from the iron manufacturer's point of view, that I cannot refrain from making use of them. Mr. Mills, in his conclusion makes out, to my mind at least, a very strong case in favour of the coal fired furnace where he refers to steam raising by waste heat. He says, "Where a high heat is present such as is necessary for rolling "off bar ingots, iron piles, and steel slabs, heat is more profitably to be "employed in raising steam than in regenerating gas. I think also that "this opinion will be greatly strengthened in the future by the adoption "of more suitable types of boilers for intercepting waste heat than has "hitherto been the custom." I think no ironmaker will feel inclined to controvert this opinion, and Mr. Mills' remark about boilers for intercepting waste heat induces me to describe later on a very excellent type of boiler for this purpose, namely, the "Cannon" boiler.

Before entering into a minute description of the Garrett furnace, I think it would be well to mention some other types of coal fired furnaces, of which I have had personal experience, as this may help us to

appreciate their respective values. To commence with, there is the ordinary open grate furnace, depending on a natural draught. This is a most wasteful type of furnace, both as regards coal and iron. We know that in order to get a low coal consumption we must have, as nearly as possible, a complete combustion of the coal gas, that is to say the products of combustion should be only water and carbon dioxide. To effect this, we must find out what quantity of atmospheric air is necessary for supplying the correct quantity of oxygen required by its (the coal gas) constituents. This air must be regulated to a nicety. A want of sufficient air allows a certain amount of carbon and useful gases to pass away unburnt, and consequently a percentage of the fuel is wasted. An excess of cold air oxidises and therefore wastes the iron and cools down the furnace to such an extent, that the volatile matters escape combustion. It will be seen from this, that both want of air and excess of air produce dense black smoke and cause an unnecessary waste of coal. In the open grate furnace, there is also great risk of the oxidising atmosphere burning the iron. Every time the furnace door is opened, cold air rushes in, the furnace loses some of its heat and the iron and coal waste is increased. Further, the open grate furnace is far too much at the mercy of the weather, which materially affects its working conditions. The disadvantages of the open grate re-heating furnace apply with equal force to the open grate puddling furnace.

The following particulars of the closed grate re-heating furnaces which are about to be changed to the Garrett type, may be of interest. The figures given are inside measurements. The grate is 4ft. 6in. long by 5ft. 6in. wide, and 20in. below level of fire hole. We use 19 to 20 grate bars, 3in. wide with $\frac{5}{8}$in. to $\frac{3}{4}$in. spaces.

Bridge from grate bars, 2ft. 3in. high. Bottom, 11ft. 0in. long by 6ft. 6in. wide. Crown, from grate bars to springer of arch, 3ft. 4in. Neck, from level of foreplate, 12in. at front tapering to 8$\frac{1}{2}$in. at back. Length to centre of stack, 5ft. by 2ft. 3in. wide.

One Firehole, 12in. square.

Three Charging doors, 17in. wide by 20in. high.

For the forced draught a fan supplies the dry air, and a blower with a steam jet having a 5-16th inch orifice (see Fig. 1) the wet air. The inlet to the grate of the dry air is 9in. diam., and of the wet air 10in. diam. Compared with the oldfashioned open grate furnace, the pressure in the grate ensures more regular working and does not leave us at the mercy of the weather—we get increased heat and therefore a greater output. The moisture imparted to the dry blast keeps the fire bars cool and prevents them burning, besides keeping the grate free from clinker, thus allowing a free passage of air through the fire. This, and the fact that there is better control over the volume of air for the more complete combustion of the fuel, decreases the coal waste. Then again, instead of irregular and uncontrolled admission of cold air through the furnace

door every time it is opened, and even when it is supposed to be closed, we find the grate with regulated pressure under it forcing the flame out of these openings and vents, which prevents the cooling down of the furnace and waste of coal and iron.

Puddling furnaces benefit in the same way with closed grates and regulated draughts. That closed grates make a much better and more regular quality of puddled iron is known to most of us, and with regard to pile heating, anyone with half an eye can see that the iron from the closed grate furnace has a much superior welding heat.

We now pass on to the Garrett furnace, Figs. 2, 3, and 4. The specification of the patent is headed "Improvements in gas producers," and says "The "invention relates to the class of gas producers in which air is blown "into a mass of coal, coke, or like fuel in a chamber to sustain partial "combustion of such fuel, the resulting combustible gas being led "away and utilised as desired, and the invention is designed to provide "a producer which will prevent clogging of the ashes and refuse below "the fuel bed." Briefly, the producer consists of (1) a perforated air box supported on a foundation built of old fire brick, and extending round the four sides of the hearth. The box is really a channel with detachable perforated fronts, which are self locking, the sides having curved ends which fit into the back and front plates. To prevent the detachable plates from falling forward, snugs are cast on the "Channel." There is nothing intricate about any of these arrangements, and a bricklayer's labourer can, if necessary, change any of the loose plates which may require renewing when the week end fettling is being done. (2) A water pan below the ground level, 5ft. wide by 7ft. 3in. long over all, and 21in deep, with a seal board 5ft. by 11in. to prevent any escape of air. The depth of this board is, of course, regulated by the pressure in the grate. The semi-circular notch at the side is for running off the overflow water. (3) A Flemish bond bridge, measuring 3 feet from top of air box by 12in. wide, with headers and stretchers course about. Air is led through a 2in. round hole in the top of the air box through 5in. by 2in. spaces in the bridge, and takes a zig-zag course, so that it meets the flame from the grate at a high temperature.

(4) Two firing doors, 12in. square are in front, and three bricked hinged cleaning doors at the end of the furnace; the centre cleaning door is 18in. square, and the others 8in. by 12in. The hot air inlets from the bridge crown are not an essential part of the furnace, and it is doubtful whether they are of much use. Originally we had fifteen 1in. air holes here, but afterwards found this number too many and closed up ten of them, as the air was being let in at a too low temperature. The air through the remaining five holes is hot enough to prevent any harm being done so far as cooling down the furnace is concerned. Theoretically, this air should aid combustion and help to clear the flame, but one may have too much of a good thing and get wasted iron and melted bridges also.

The water box on top of the air box (see Fig. 2) may also be regarded as of little or no importance, at least so far as Scotch coal is concerned. We tried this in the first furnace put down, with the object of preventing "clinker" from adhering to the air box; but, as a matter of fact, we have not experienced any trouble of this sort in the furnaces fitted without it.

We will now turn our attention to the working of the furnace, commencing with the blast arrangements. Each furnace requires 4,000 cubic feet of air per minute. This is supplied by a fan capable of giving 20,000 cubic feet of air per minute against a head of $4\frac{1}{2}$in. W.G. The fan is an open one, so that any excess air churns back. It is belt driven by a 15 h.p. reciprocating engine. The air is discharged into a 26in. diameter sheet iron central main, and branches 12in. diameter are led right and left to each furnace. A butterfly valve within the reach of the furnaceman regulates the blast to suit the condition of the iron in the furnace.

In lighting up the furnace, we first fill the water box with well burnt rough ashes as far out as the seal board and up to the top of the air box. Live coal is shovelled in through the firing doors and equally distributed over the bed of ashes; water is then run into the pan, and the ashes become so thoroughly soaked that the heat from the fire above causes sufficient moisture to mix with the dry blast to prevent heavy clinker forming and clogging on the air box. The blast is now turned on, and as it passes through the perforations in the box, it combines with the fuel in the ordinary manner, forming gas, which passes over the hot air bridge into the furnace, and after performing its work there, the spare gas is passed through the neck to the boiler and then up the furnace stack. As the ashes from the consumed coal accumulate above the air box, they are reduced to their correct level by removing the necessary quantity from the bottom of the water pan. There is no difficulty in doing this, as the cross-sectional area of the air box is greater at the bottom than at the top, thus allowing the free discharge of the ashes into the water pan. The cleaning doors are opened twice each shift for the purpose of removing clinker and freshening up the fire bed generally. At our works this is done by a labourer when the heater is charging, so as to save time. The opening of the doors, cleaning and sealing them up again with fireclay, does not occupy more than fifteen minutes. This done, the cleaner comes round to the front of the furnace, turns on the blast and fires the furnace, so that before the furnaceman is finished charging, the heat in the furnace is as good as if no cleaning had taken place. I am aware that as a general rule, furnacemen are expected to do their own cleaning, but in order to get the full advantage of the Garrett Furnace, we think it wiser to employ labourers to do this work When I mention that the furnaceman very often deals with 18 to 20 tons of piles, varying from 100 to 120lbs. each, in one shift, I think you will agree he has quite enough to do

without having his grate to clean. Below I give particulars of the cost of altering an ordinary grate to the Garrett type, with detail of necessary castings, bricks and labour :—

CASTINGS.

	Cwts.	qrs.	lbs.		£	s.	d.	£	s.	d.
1 End Plate with 3 Cleaning Doors	12	2	0	say	2	19	0			
1 Top end Plate	11	0	0	,,	2	12	0			
2 Firing Door Plates	22	0	14	,,	5	5	0			
2 Side Plates	20	2	0	,,	4	17	0			
1 Large Cleaning Door ...	1	0	5	,,		7	0			
2 Small Cleaning Doors ...	2	0	0	,,		13	0			
2 Firing Doors		1	3	,,		2	0			
1 Set of Air Boxes complete...	25	1	0	,,	10	2	0			
1 Water Pan	7	0	0	,,	7	10	0			
								34	7	0

BRICKS.

1700 Squares in Grate				say	4	11	0			
700 Crown Bricks				,,	2	4	0			
1 ton Fireclay				,,		6	0			
								7	1	0

TIME.

Pulling down old Furnace—2 Labourers 1 shift each				say		9	0			
Building new Grate—2 Bricklayers 1 shift each				,,		16	0			
Building new Grate—3 Labourers 1 shift each				,,		12	0			
Erecting ironwork—1 skilled Labourer ½ shift				,,		3	0			
Erecting ironwork—2 Labourers ½ shift each				,,		4	0			
								2	4	0
Fitting Doors, &c., including Material ...				,,	4	0	0	4	0	0
Total ...				...				£47	12	0

Many of the leading points in favour of the Garrett grate will have already occurred to you from my description of its construction, &c. We have already considered the open grate furnace and I have tried to show how inferior it is to the ordinary closed grate furnace. If any further proof be needed, you have but to refer to the comparative statement of

coal consumption, &c., to which your attention will be directed shortly. The advantages of the Garrett type compared with the closed grate are many. To instance the main points :

(1) We have a valve giving us a more complete control of the air which is admitted into the furnace through the numerous small orifices in the air box, and as we know that a given quantity of air is necessary for the combustion of the gas evolved from the coal, these advantages are obvious.

(2) The hot air from the hollow bridge meeting the escaping gases as they pass over into the furnace, before their temperature has fallen below that of ignition, is of great service, inasmuch as it aids combustion without reducing the temperature in the furnace.

(3) Increased output and reduced coal and iron wastes.

(4) The saving of steam through steam jets being dispensed with. This item is worth more than a passing thought. Suppose for the purpose of forced draught an inch pipe is used with a $\frac{3}{8}$ in. orifice, the coal necessary to supply the steam works out as follows :—

Steam Pressure—Seconds.

$$\frac{60\text{lbs.} \times 60 = 3.600}{70} = 51{\cdot}4\text{lbs. of steam per minute per square inch of Orifice.}$$

Diameter of Orifice—Area $\frac{3}{8}$in $= {\cdot}11 \times 51{\cdot}4 = 5{\cdot}6$ lbs. of steam per minute.

Minutes. $5{\cdot}6 \times 60 = 336$lbs. of steam per hour.

Say 1lb. of fuel evaporates 7lbs. of water, then—

$336 \div 7 = 48$ lbs. of fuel per hour each jet.

(5) The advantage of being able to maintain the temperature in the furnace through having neither grate bars to clean, nor ashpit doors to open to remove the ashes.

(6) The more even temperature in the furnace, and hotter waste gases, give us much more steam.

(7) The saving of the cost of grate bars.

Against this last item we have to allow for the renewal of one of the loose perforated plates, weighing 200 lbs. every 4 or 5 weeks. The other parts of the box never require replacing—at any rate we have had some of them in constant use for three years, and they are as good now as the day when they were first put in.

Before considering the tabulated results of fuel consumption, &c., I may just mention that with regard to the other parts of the furnace, there is nothing out of the ordinary. The bottom is a sand one built up in the usual manner with old brick, &c. The size of the heating surface is 12ft. × 6ft. 9in. The unused gases pass into various types of boilers—Cornish, Lancashire, and Cannon. The two first-named types are 20ft. 0in. × 7ft. 6in. and the spare gases travel through the flues, split at the end, back along the sides, through to the downtake under the boiler, and then up the stack. The Cannon boiler is described later on.

CLOSED-GRATE FURNACES, COMPARED WITH GARRETT PATENT.

Mill.	Closed-grate Furnaces with steam jets.			Garrett Patent Furnaces.			In favour of Garrett Patent.			Sizes, etc., rolled.
	Average Output per shift.	Coal per ton of finished iron.	Furnace waste per ton of iron charged.	Average Output per shift.	Coal per ton of finished iron.	Furnace waste per ton of iron charged.	Increased Output per shift.	Reduced coal consumption	Reduced furnace waste.	
11″ Guide	T. C. 22 6 2 15	C. 10 3 14	12·5 %	T. C. 24 19 0 5	C. 9 1 19	10·8 %	T. C. 2 12 1 18	C. 1 1 23	1·7 %	⅜in. to 1 5-16in. dia. ½in. to 1⅛in. squares. 2in. to 3½in. hoop strip. ¾in. to 2in. flats. Small channels and H iron. Small angles and tees.
14″	T. C. 20 1 0 0	C. 10 0 16	10· 9%	T. C. 22 12 0 4	C. 8 2 6	8·8 %	T. C. 2 11 0 4	C. 1 2 10	2·1 %	1½in. to 3in. dia. 1½ to 3½in. squares. 4in. by 12in. W.G. to 8in. hoops strip 2in. to 8in. flats. Angles, tees, and rails.

NOTE.—Closed-grate furnaces mean furnaces with closed ashpit doors with steam jet in a hollow grate. The other mills under the writer's control cannot be compared, as the Garrett patent has not yet been adopted in them.

The figures of the respective statement are the results of careful weighings of the coal as it was fired each day on weighed barrows, which were brought into the furnace, and the iron taken from the finished bars was also specially noted after and weighed. The test lasted for a week, and was taken several months. The coal used is Scotch splint and was drawn by lorry. The iron used is finished rods including lighting up and steam raising. With regard to the latter we are entitled to deal with them as in the case of iron produced. The conclusion is arrived at as follows:—The puddling and re-heating furnaces at the works where the Garrett system of furnaces are in operation evaporate 7·25 lbs. of water per lb. of coal, and the actual figure has been taken at 7 lbs. as an approximate basis. Then 7 lbs. of water per lb. of coal. Assuming a Wm. Fairbairn & Lancashire boiler at least 10 per cent. which is the average duty of our boilers evaporates per lb. of Lancashire coal from and at 212° Fahr. which is about the temperature of the water pumped into our boilers as the supply from a 200 feet main, 7·70 lbs. of water and the same boiler under similar conditions fired with Newcastle slack evaporates 8·32 lbs. per lb. of fuel. For the purpose of my calculation I have taken the lower evaporation, namely, 8·32 lbs. for the following reasons: 12 of the 16 boilers at the works under review, and evaporating, as has been said, 6·94 lbs. of water, belong to the puddling department, and therefore for about an hour each shift the firing slackens off. Whereas the mill boilers attached to the Garrett furnace have an even temperature about them throughout the entire shift, and therefore evaporate their 8 lbs. of water probably quite 8 lbs. Instead of comparing the practice of the Lancashire boiler mentioned, with 9·36 lbs. against our mill boilers 8 lbs., I prefer to deal with 8·32 lbs. against 6·94 lbs. (which amounts to about the same thing), as there is no doubt about the last mentioned figures. This leaves us with 1·38 lbs. of water, which would have been evaporated had the boilers been specially hand fired, or in other words only 16% of the total fuel consumed per ton of iron produced is used in heating the iron.

I am aware that an evaporation of 6·94 lbs. of water per pound of fuel is more than many works manage, although this result is not uncommon in the Lancashire district, where there are many excellent furnaces independent of the Garrett type. Of course, furnaces working with a natural draught cannot expect such results from the boilers attached to them. In this case 4½ to 5½ lbs. would be good work, and if the forge and mills were only equally balanced so far as puddled bar requirements are concerned, hand fed boilers would in all probability be needed to help the steam.

With regard to the average output, it must not be imagined that this is all the furnaces are capable of heating. If I were to take odd shifts,

I could give you many where two furnaces have heated from 30 to 40 tons of finished material in twelve hours, but this would manifestly be unfair. The low average output is due to excessive roll changing, and, of course, the coal and iron wastes suffer too. This remark applies equally to both types of furnaces The time occupied in heating from 3 to 3½ tons of piles varies from 50 minutes to 1 hour 20 minutes, according to the number and weight of the piles in each heat.

At the commencement of this paper I made reference to the Cannon boiler. This is the local name given to it, but it is really a combined boiler. The following particulars as to its construction and our method of working it may prove of interest to you.

It is fed from a hot feed tank, into which the mill engines exhaust, with water at a temperature of 200° to 212° Fahr. more often than not, the latter. The evaporation per pound of coal is from 7 to 8 lbs. of water, which I think you will admit is excellent practice. The horizontal boiler is above, and the vertical boiler at the flue end of the furnace. They have a single flue through which the waste gases pass into the stack. The two boilers are fed from the stool in the upper boiler, and the water gravitates through the bottom pipe into the lower boiler,the steam passing out of this boiler into the horizontal one through the tube at its crown. The upper boiler is 20ft. 0in. × 6ft. 6in. A brick neck, three courses, carried by an angle bar connects the two boiler flues. The steam from the combined boilers is led into the steam main from the horizontal boiler.

There is a general objection to placing boilers above the furnace, because, as a rule, boilers so placed are not such good steam raisers as those placed at the end of the furnace; and also because the furnace draught is to some extent checked. My own experience confirms these objections, particularly if the boiler above the furnace happens to be a Lancashire Boiler and depending on a natural draught. It sometimes happens, however, that one cannot afford the floor space to place the boiler on the ground level, in which case I know of no better boiler than the Cannon type. Instead of leading the hottest of the waste gases to the boiler above the furnace. through a stack consisting of 850 to 1,000 best fire bricks, which have to be renewed every three or four months, through being uselessly burned away, you have a vertical boiler receiving these waste gases and raising steam. From my late experience of the Cannon Boiler I feel convinced it is the best, the safest and cheapest for the purpose of utilising waste heat from mill furnaces. In conclusion, I have to thank Mr. Sutherland, our works engineer, for preparing the sketches and the diagram on the wall.

THE DISCUSSION.

THE PRESIDENT: I feel sure you will agree that the paper has been a very interesting one. It is a fact generally recognised, I think, that the

capacity of guide rolling mills in Staffordshire, as in Scotland, considerably exceeds the capacity of the furnaces usually employed. Mr. Garrett's furnace is no doubt an admirable one, but it does not quite provide all the advantages possible in a properly designed mill furnace. I erected a special form of furnace at the works of a friend, which has given very good results; the air being admitted under pressure and at a fairly high temperature. The air was heated by radiating heat, and an equal distribution of heat in the furnace was under the control of the furnaceman Mr. Garrett does not agree with my method, as he contends that in heating the air, the temperature of the furnace is reduced; but this idea is not proved in practice, and the furnace is working well and economically.

Whether a gas furnace may satisfactorily be employed in connection with rolling mills depends entirely upon circumstances, and it is a great mistake to substitute a gas furnace for a coal fired furnace which is generating steam, unless there are some very unusual conditions. It appears from Major Trinham's paper that a Garrett Furnace provides a much-needed improvement in the method of heating iron piles. The figures given—9 cwt. of coal per ton of finished iron, and at the same time evaporating about 8lbs. of water in a boiler per lb. of coal—are almost incredible.

We shall be pleased to hear what has been the experience of those members who have tried both kinds of furnaces.

PROFESSOR TURNER: I cannot claim to have any special experience of the Garrett Furnace. At the same time, though I am strongly in favour of heating by gas in many cases, yet I am prepared to admit that there may be instances where direct firing may be advantageous. Not that theoretically there is anything unsatisfactory in the use of gas, provided, of course, that there is suitable regeneration. But with a mill furnace for iron there is the incidental fact that it is necessary to raise steam, and that steam is required at the same time as the furnace is working. The steam is required for the rolls at the same time as heat is needed for the metal which has to be rolled. I am not in favour of the principle recommended by the President of taking the heat from the outside. That is the old Boetius system, and was used by Mr. Smith-Casson at Earl Dudley's works, and he got satisfactory results; but I believe I am correct in saying that there are none of those furnaces working at the present time, and I think the same results may be obtained in a more direct way. I agree with Mr. Garrett as against the President that it is merely taking heat from one point to put it in at another point of the furnace. In this case you want a higher temperature further on when you are coming into the working part of the furnace, and when you have got out of the gas producing stage. I don't see that there is any advantage in taking a certain amount of heat from outside the gas producing part of the furnace and putting it in

at the end of the process. But I am quite willing to admit that where steam is required side by side with a re-heating furnace, it might be advantageous to have direct firing as adopted in the Garrett Furnace. The one disadvantage of a properly worked gas furnace is that the heat is so utilised that there is no excess available for raising steam. Or to put it in another way, it is obviously impossible to save the heat by regeneration and also to use it for raising steam.

Mr. HERBERT PILKINGTON, M I C.E. : I have been for some years in search of a satisfactory heating furnace, and have gone through very varied experiences with several types. I could not help thinking from the remarks of the President, as to his experiences with the one he had got hold of, that it was very much in the line of the one I had experimented with.

It is a fact, not altogether peculiar to heating, that you cannot have the benefit of fuel economy at one end of the stick, and at the same time economise by steam raising at the other. If you save fuel in the furnace by complete regeneration, as in the new form of Siemens Furnace you lose the considerable advantage of raising steam by the waste heat, and this furnace, satisfactory as it is as a heating furnace seems to me, when compared with the ordinary open grate furnace, heating boilers with the waste heat, to be just about change for a shilling in its ultimate economy. You save fuel in the Siemens Furnace, but you lose it in fuel expended under firing boilers. I do not think there is any real economy.

In our iron mills, frequent roll changing, owing to the miscellaneous nature of the orders, is such that, may be, the Siemens Furnace has not the best of chances. With the furnaces on steel, however, with a larger output and regular work, their results are more satisfactory. This means that there must be a large continuous output in order to obtain the best advantage from these gas furnaces. Even then, I believe, that the old open grate furnace will beat a Siemens Gas Furnace as regards waste of iron or steel, added to which the waste heat going under the boilers has the advantage of raising steam for nothing. It did appear to us, however, that the desired furnace was one capable of steam raising with lesser consumption of fuel than the old open grate furnace, but it is difficult to say what form this furnace should take, as it appears somewhat contradictory to save fuel and also increase the amount of evaporation in the boilers.

In the furnace described by the author, this, however, has been accomplished; that is, more water has been evaporated and some fuel has been saved, and this seems to me to require some explanation. I have been experimenting with a new type of furnace for six months with this end in view, or rather with a view to maintaining the existing evaporation in the boilers and save some of the fuel consumed at the same time; but I regret to say I cannot record very satisfactory results.

We used a closed producer, built in the end of the furnace, and partial regeneration by forcing air through hollow bricks in the roof, this hot air meeting the gas from the producer through suitable ports at the producer end of the furnace. The producer was so constructed that we had a certain mixture of producer and water gas, the object being, by the use of air heated by partial regeneration, to bring the gas into an intense combustion at the ports, The fuel consumed, however, showed no economy over the old type, and the furnace was abandoned.

I am rather astonished at some of the results which the author has recorded, but it does not appear quite clear as to how crop ends are dealt with in the coal consumption. The table says, "Coal per ton of finished iron." Is that per ton of finished iron sold or is t finished iron plus crops? The author gives the ordinary consumption as 13¾ cwts. of coal in the open grate furnace. This appears to me to be an excessive quantity by at least a couple of cwts.

I may say that at Sheepbridge Works, we regularly weigh everything in and weigh everything out, so that in trials of this nature no one knows that special notice is being taken of the working. I well know what results frequently happen when special trials under close observations are made; consequently I should like to know whether the author weighs his materials in and out regularly, year in and year out, and how the crop ends are dealt with in the computation.

Also, I have never found a means of determining the evaporation in mill or puddling furnace boilers, which is altogether reliable. No method of measuring water is satisfactory except by the use of tanks, and a very large series of lengthy observations under the varying conditions of working are necessary to obtain reliable figures, and from such a large series of observations as this, I make out that 3½lbs. to 4½lbs. of water is evaporated per lb. of fuel by our puddling furnaces. Unfortunately, I have no open grate mill furnaces left to experiment with. Knowing then of the many little errors that creep into these trials, I am curious to know how the water consumption is measured.

I am bound to say that if this furnace gives the results recorded, it is a very valuable furnace indeed.

Mr. T. ASHTON: The admirable paper brought before us to-night by Major Trinham will help to solve that much debated question, whether for re-heating purposes—in iron mills particularly—a gas furnace is more economical than an improved coal fired furnace. The extracts already given from the paper read by Mr. Fred Mills before the West of Scotland Institute, and also the opinion given by Ganot, the French scientist, are most valuable contributions to the settlement of the question, and well deserve a careful reperusal. The trend of their remarks is distinctly in favour of the direct fired furnace, and even such a progressive scientist as Mr. Pilkington speaks with very faint praise of gas furnaces, as he considers the advantages and disadvantages about

equalise each other. As to the great heating power of the New Form Siemens furnace, no one can dispute it, the main objections which prevent its general adoption in iron and steel works are its enormous initial cost and its inadaptability for steam raising purposes.

Attention is now directed towards improving the direct fired furnace, and therefore we cannot fail to be interested in the discussion of the Garrett Furnace so ably described to us to-night by Major Trinham. This furnace has much in common with others of ordinary type working with forced draught. Its main novelty being a water pan placed underneath the grate, or producer, taking the place of the usual grate bars. Into this pan a layer of ashes is thrown, then covered with live coal, after which the ashes are saturated with water, which prevents clinkering, and also helps to form a combustible gas to be utilised in heating the furnace. From this stage the usual firing is continued, and with the aid of forced air (without steam jet) producing all the combustion required for the successful heating of the furnace.

Many points in favour of this furnace have been brought before us to-night, and as many of our members had the pleasure of seeing it in operation when visiting the Waverley Iron Works at Coatbridge in August last, I think they will agree with me that Major Trinham has in no way overdrawn the picture, but that the furnace undoubtedly possesses the advantages he claims for it.

A few of the special features are—a larger output with a reduction of nearly 2 per cent. in waste of iron charged, with a less consumption of coal of 1½ cwt. per ton of finished iron, when compared with a closed grate furnace working with steam jet. And further, the small outlay required (estimated to be less than £50) to alter an ordinary furnace to the Garrett type, and utilizing the waste heat for raising steam.

Evidently the Garrett Furnace is being framed on the right lines, and unless gas furnaces are much more simplified and made less costly, this and similar types of furnaces, with further improvements, will successfully compete with them, at any rate for iron if not for steel mills.

Mr. CROFTS: My experience leads me to believe that the old-fashioned furnace, when modernised, cannot be beaten. I visited three or four places recently where all the steam is raised by the mill furnace boilers with the old-fashioned grates. This is a very good furnace I will admit, and I have seen it at work; but the biggest misfortune about any of these furnaces is that the men cannot be induced to attend to them. Mr. George Adams, of the Mars Ironworks, sent a man to America to get the latest thing, and it was put down, but they could not get the men to attend to it. And my opinion is the same with regard to this furnace, namely, that it will be a failure unless men are specially kept to look after it.

Mr. BUSHELL: We are rolling strip and have one of these furnaces at work. I hardly like to say anything about it with regard to waste of

heat as we have not had it very long; but there is one point I am rather impressed with, and that is the difference in the fuel in the two districts. The fuel in this district is rather different. In Scotland they have a nice hard coal which does not clinker much, but here the coal does clinker a lot, and the loss of time in cleaning the grates here is therefore very considerable, and it is very hard to get the men to give proper attention to the furnace. They are very stupid and so half trained. I am sorry I cannot throw much light upon the difficulties as to heat, &c. Perhaps at some future time I shall be able to say a little more about it.

THE PRESIDENT: Mr. Bushell, who has just spoken, has two of these furnaces at his works, but they have not been at work very long.

Mr. RD. EDWARDS: We are very much indebted to Mr. Trinham for coming down from Scotland to-night. It shows that excellent spirit existing between ourselves and our friends in Scotland, which was exemplified in their hospitality when we went up there. I had the pleasure of seeing these furnaces at work during our recent visit, and they seemed to work very well and to give very good results. Of course up in Scotland they have a better fuel, which gives a stronger and longer flame. I should like to see a model heating furnace, but I am afraid it is very hard to get the men to see eye to eye with you in this matter.

Mr. A. R. BANKS: We have a furnace working with a closed grate, which is very much more satisfactory than an open grate. The consumption of fuel is much less and the waste of the iron is also much less.

MAJOR TRINHAM: I am much obliged to all of you for the patient hearing you have given me, and particularly to the gentlemen who have been good enough to enter into the discussion. The President has mentioned the advantages to be gained by heating the blast before it enters the furnace, and Professor Turner and Mr. Pilkington have given their views on this point, showing certain disadvantages of doing so. This is a matter I have not dealt with in my paper, and although in the main I agree with Professor Turner and Mr. Pilkington, I am also of opinion that, considering the high temperature of the escaping gases after they have done their work in raising steam, there is sufficient heat left to raise the ingoing air to 500° Fahr. by means of a properly constructed air-blast pipe placed within brickwork at the entrance to the chimney. If such an arrangement could be carried out, I calculate it would result in a further saving of about 1 cwt. of coal per ton of finished iron. I don't think I am far out of it if I put the temperature of the escaping gases at the flue, after doing all they are capable of under ordinary boilers, at 1,200° to 1,500° Fahr., with the result that the chimney for several feet up is heated to redness. Considering it is not necessary to have more than 500° to 600° Fahr. for inducing a good chimney

draught, I think we could profitably turn our attention to utilising this wasted heat. It is a matter I intend giving some thought to.

Mr. Pilkington asked about the crop ends, and wanted to know how they are dealt with. First of all, every pile is weighed before charging, then after the crops are taken off, their weight is added to the saleable bars, the difference between this total weight of bars passed through the rolls and the actual weight charged is the furnace waste, or "shrinkage." In the 11 inch mill this turned out to be 10·8 per cent. and in the 14 inch mill 8·8 per cent. The difference between these results is of course accounted for by the greater number of small piles per heat in the 11 inch mill as compared with the heavier and smaller number of piles in the 14 inch mill. The coal is weighed in wagons, as they enter the works, over the weighbridge. The "coal per ton of finished iron" is calculated on the iron sold, and not finished iron, plus crop ends; it also includes lighting up. As already mentioned in my paper, the tests, &c., extend over several months—to be exact six consecutive months—they were recorded in our usual way of working and not specially for the purposes of this paper. Had I desired to give you some fancy figures, I could have picked many odd 12 hours' shifts with outputs from two furnaces of 36 to 40 tons of saleable bars. I could have given you odd months with an average of 27 tons per shift, after changing 80 pairs of rolls In many instances the furnace waste could have been made to read, when favourable orders were in hand for the 11 inch mill, 8·5 per cent., and the 14 inch mill 8 per cent., instead of 10·8 per cent and 8·8 per cent. respectively, and the coal consumption, when these big outturns on odd shifts were made, would of course have been much lower. I think I have already explained in my paper how less coal is consumed per ton of iron produced, and how more water is evaporated by the "Garrett" type of furnace, combined with a properly-regulated forced draught. Mr. Pilkington also asks how the water consumption is measured. Briefly thus: the water is pumped into the boilers by a Blake-Knowles Duplex Pump; the tank from which the water is drawn is 5ft. above the suction branch of the pump, which would give roughly a pressure of 2½lbs. on the suction side; this of course prevents excessive plunger slip and so reduces the usual allowance of 10 per cent. to 5 per cent., which figure I have used for allowance in measuring the water evaporated per lb. of fuel used. The measurement was taken in the usual way, namely, the number of strokes per minute carefully counted, multiplied by the capacity of the water cylinders.

I now turn to Mr Ashton. From his remarks I gather he has not only done me the honour to read my paper very carefully, but he has minutely studied and grasped in every detail the actual working of the "Garrett" Furnaces. It must not be understood that I am setting the

"Garrett" Furnace against Siemens' New Form Heating Furnaces. Mr. Ashton has grasped my meaning pretty well, namely, the improvement at a small cost of our present good, bad, or indifferent ordinary closed grate furnaces. I am much obliged to Mr. Ashton for his practical and sympathetic remarks. Mr. Crofts and Mr. Edwards complain of the great difficulty in getting workmen to adopt new ideas. I agree with them; the success of the "Garrett" Furnace was certainly not due to the workmen, but to the people in charge of the mills.

There is something in Mr. Bushell's remarks about the coal which is best suited to this furnace. Hard coal is better than soft; but he must not think we always use hard coal, it can't always be got, then we have to use soft coal. This means the furnace requires extra cleaning per shift, but as this is done at the proper time the working of the furnace is not interfered with to any appreciable extent.

I am much obliged to Mr. Edwards for his appreciative remarks. He makes mention of the recent visit of the members of the Institute to Scotland and the good feeling which exists between the two districts. I feel sure it will be to the benefit of all concerned to maintain, as I am sure we shall, that good feeling, expecially in matters relating to our own trade. It is only by a free exchange of ideas that we can hope to successfully meet foreign competition. I am glad to note Mr. Banks' experience coincides with my own, viz., that closed grate furnaces are preferable to open grate furnaces.

THE PRESIDENT: I have known Major Trinham for a number of years and can vouch for the accuracy of his figures, and considering he is not in any way connected with the patentee of the furnace, we must, I am sure, feel indebted to him for the useful information. The actual merits of this furnace are—(1) Reduced coal consumption; (2) Increase yield of iron piles; (3) Greater quantity of water evaporated. Proprietors of ironworks in South Staffordshire will do well to carefully consider these detals. I propose a cordial vote of thanks be given to Major Trinham for his paper.

Mr. W. J. ONIONS: I have very great pleasure in seconding the vote of thanks, and I do so cordially.

The resolution was carried unanimously by acclamation.

MAJOR TRINHAM: I am much obliged to you for your vote of thanks, and beg to assure you it has been a real pleasure to me to come here to-night. The discussion which my paper has provoked, and the generous criticism of its details has amply repaid me for the little trouble I have taken.

This concluded the proceedings.

The Fifth Meeting of the Session was held at Dudley, on Saturday, January 21st, 1905.

THE PRESIDENT (Mr H. B. TOY) presided.

The minutes of the last Meeting were read, approved, and signed.

Messrs. George Carrington and Albert Williams were elected members of the Institute.

Mr. C. E. Tarbolton then read the following paper, which was illustrated by lantern views and a working model.

THE STIRLING WATER TUBE BOILER, with Notes on the Purification of Feed Water by the Thermal System.

By CYRIL E. TARBOLTON.

Water tube boilers are by no means a novel invention, but the problems involved in the correct design and construction of this type of boiler have only recently been fully appreciated, and it is curious to see how incorrect designs continue to be manufactured and to find a market, though practical experience is beginning to eliminate the defective designs on account of the difficulties experienced in actual working.

The advantages of the water tube boiler at sea over the older cylindrical boilers of the marine type are considerable, on account of the special conditions of the case, such as the great saving in weight and space occupied and their capacity for quick steam raising.

The advantages of the water tube boiler over older types on land, however, are not quite so obvious, and it is therefore proposed to put before you some of the claims that are made for its superiority in this service.

Considering the question from the economic point of view, the chief points to be aimed at in the design of generating plant are:—

(1) Economy in working.
(2) Economy in maintenance.
(3) Economy in first cost.
(4) Safety.

Let us then consider these various points, when it is submitted that considerable advantages are possessed by the water tube boiler under each of the headings. This will bring out some of the more important points to be kept in view in the design of a satisfactory boiler of this type, and these may be subsequently discussed in detail.

Economy in Working.—To get the highest economy of fuel it will be necessary to employ multiple expansion engines and high pressure steam. This is a matter which is well understood and will need no further demonstration; it mainly affects the engines, but must be considered in relation to the boilers, as will be seen later in considering the first cost.

The most important point under the above heading is the fuel consumption, *i.e.*, the quantity of water that can be evaporated per lb. of

coal, or, in other words, the "efficiency" of the boiler. For the purpose of comparison between two boilers the efficiency is the usually adopted factor. It may be defined as "the amount of heat taken up by the water compared with with the amount of heat generated by the complete combustion of the fuel." Thus, if a boiler is said to have an efficiency of 65 per cent., it means that that proportion of the total heat generated on the grate is accounted for by the steam produced, the remaining 35 per cent. of the heat generated is loss, mainly in the heat carried away by the waste gases, incomplete combustion, and also a small amount by radiation. The efficiency, of course, is independent of the quality of coal or of the special conditions under which the test is made.

In Mr. Bryan Donkin's work "The Heat Efficiency of Steam Boilers," a record is given of over 400 careful boiler tests on various types of boiler and under all conditions. It is not fair to argue from single tests, but here we have a large number for each type of boiler, and may be justified in taking the average results as fairly representing the efficiency of the different types of boiler.

From 107 tests of Lancashire boilers given in this book the efficiency works out at 62·4 per cent. Unfortunately there is not an equal number of tests given from the water tube boilers, but these head the summary of averages with an efficiency of 77·4 per cent.

The Stirling boiler represented by the model before you shows, according to Mr. Donkin, an efficiency of 76·6 per cent. An average of the ten tests on Stirling boilers, working under varying conditions, which are given at the end of this paper, shows 75·8 per cent efficiency. In this connection the extremely high efficiency (84·9 per cent.) of the boilers fixed at the Sheffield Corporation Lighting Station should be noted. These are probably the largest boilers that have ever been constructed in one unit. The actual evaporation was 44,356 lbs. of water per hour per boiler, equivalent to over 2,200 h.p. at 20 lbs. steam rating.

In making comparison with the Lancashire Boiler then, we are well within the mark in taking the efficiency of a properly designed water tube boiler at 74 per cent. This, compared with the Lancashire boiler, represents a saving of about 15 per cent of coal.

Roughly speaking, one may say that with a water tube boiler the same efficiency will be obtained as with a Lancashire Boiler and Economiser, and without the increased cost and maintenance involved by the latter apparatus.

Other advantages in working are, that much larger units can be employed when considerable power is required. The 30 by 8 Lancashire boiler can evaporate at most about 7,500 lbs. water per hour, whereas water tube boilers are now being made to evaporate from four to six times that amount. This reduces the first cost very considerably for large units,

and also brings down the charge for attendance, as it is obvious that a large boiler can be worked with fewer men than, say, four boilers of the same output.

As an instance of the saving in floor space. A Lancashire Boiler and Economiser require, roughly, 650 square feet, whereas a Stirling boiler of four times the capacity would occupy less than two-thirds of this space.

Economy in Maintenance.—This is where steam users frequently put the water tube boiler out of court without a hearing, but, when the boiler is properly designed, the cost of cleaning and maintenance is actually less than in the older types of boiler, in which the only method of cleaning is by chipping by hand over its internal surfaces. This is a matter which must be emphasized, as it is commonly urged as one of the objections to the water tube boiler that it is impossible to clean them. But, if preconceived ideas are put on one side and the matter considered impartially, is there any reason why a simple mechanical contrivance should not be designed to enable the internal surface of the tubes to be cleaned quickly and thoroughly?

One answer to this question is on the table before you in the shape of a very ingenious mechanism that has been found of great practical value. It consists of a small turbine, the rotating parts of which carry arms and cutters. The whole turbine is dropped into the tube from the upper end and is connected by 1¼in. hose pipe with the feed pump or other water system at from 100 to 140lb. pressure The water having been turned on, the turbine is caused to rotate at a high speed and the tapping motion of the arms rapidly removes the scale from the tubes; while the exhaust water washes this down in advance into the lower drum.

A well designed water tube boiler will be quite free from strains due to expansion and contraction This cannot be said of many internally fired boilers, in which the plates surrounding the furnaces acquire a higher temperature than the rest of the boiler when scale is present. For example, in a boiler with scale one-eighth of an inch thick the temperature of the furnace plate may be 250 degrees in excess of that of the water, consequently when cold air is admitted during firing, there will be a rapid reduction of temperature and a corresponding contraction. With a drop in temperature of 200 degrees this contraction would be about one-eighth of an inch in the length of 8 feet. Lancashire boilers are to a certain extent elastic, but less so when constructed for higher pressures, and it is small wonder then that this constant straining, which occurs every time the fire door is opened, leads to grooving at the furnace flanges.

Economy in First Cost.—It is not proposed to give actual comparative figures under this head, but it may be indicated where the advantage

lies with the water tube boiler. It may be designed to work at high pressures with very moderate scantlings and with a high factor of safety, whereas, for high pressure cylindrical boilers the thickness of plates becomes very great, with a proportionate increase in the cost.

Where large units are employed there is a further saving in the brickwork, fittings, piping, and accessories generally.

Safety.—Though this consideration is really of the first importance, it is dealt with last, because, whatever boiler is adopted, precautions must be taken to prevent any possibility of accident. At the same time there is much in favour of the water tube type of boiler. The drums are not exposed to the direct action of the flames, and the worst accident that can happen, due to low water or carelessness, will be a tube giving out. In the cylindrical boiler the consequences of an accident from low water are much more serious.

Having put forward the claims of the water tube boiler from the economic point of view, it will be well to examine into the causes which conduce to this higher economy in working.

Briefly these may be ascribed to the efficient combustion of fuel, the circulation, and the better arrangement of the heating surface.

For perfect combustion of fuel, and in order to insure the maximum initial temperature, the boiler must have either an external furnace, or the furnace lined with fire-brick. The importance of a high furnace temperature lies in the fact that the rate of the transmission of heat through a boiler plate is proportional to the square of the difference in temperature on the water side and the fire side. As from 50 to 70 per cent. of the total evaporation takes place in the immediate vicinity of the furnace, the more work that it is possible to do here, the better, as the increase in the final temperature will be comparatively slight.

Combustion should also be complete before the hot gases reach the heating surface of the boiler, otherwise there is a danger that they be cooled down prematurely, part of the gases thus passing away unconsumed.

The furnace must be designed to take advantage of any cheap fuel available, and it has been found by experience that "gum," "smudge," fine slack, etc., can be burnt with high efficiency, and with ordinary natural draught, in a boiler fitted with a fire-brick combustion chamber, whereas this kind of fuel cannot, as a rule, be burnt in a cylindrical boiler without forced draught, or other special apparatus, which causes a large proportion of this light material to be blown into the flues. Moreover, a sufficiently high temperature cannot be maintained in the furnace, so that the efficiency of the process, when possible, is low.

The type of furnace has, of course, a direct bearing on the smoke question. There is, perhaps, no subject upon which ideas differ so much as upon smoke prevention, and the number of appliances and patents

taken out for this purpose is wonderful, especially as the principles applied are so contradictory.

The main consideration is that combustion should be complete before the gases come into contact with the boiler, and that ample space should be provided for their proper mixing. The method of firing is, of course, another important point, and there is no doubt that the "coking" method is the correct one, *i.e.*, bringing the green coal forward slowly from the dead-plate as is done by the "Chain grate" and other mechanical stokers of the kind. Guarantees can be given by the makers as to the entirely smokeless working of water tube boilers fitted with these contrivances.

With regard to the circulation in boilers, it must be rapid, continuous, and in the same direction throughout. It may be useful here to give the causes of this circulation, as summed up by Professor Wilkinson in a paper before the Institute of Naval Architects :—

"(1) The difference in density of the water due to its difference in temperature when the fires are first lighted. This circulation is very sluggish.

"(2) When the water is all at approximately the same temperature and steam is being generated, but not with sufficient rapidity to cause a break in the continuity of the water, a much more vigorous, but mainly local circulation. is set up by the entraining action of the bubbles of steam rising through the water.

"(3) When steam is generated with such rapidity that in some part of the circuit there is steam or foam only present, a very rapid circulation results from the difference tn density between thi · steam or foam, and the continuous water in other parts of the circuit."

The water tube boiler has the advantage that the circulation can be divided and controlled by the designer.

Besides keeping the boiler at a uniform temperature with consequent elimination of strains, etc , the circulation greatly increases the efficiency of its heating surface by removing the bubbles of steam immediately they are formed. If these bubbles adhere to the surface, even momentarily, they act as non-conductors, and materially diminish the heat absorbing property of the tube surface and so affect the efficiency of the boiler. It may be said that an effective bubble removing circulation is nearly as necessary to efficient heat transmission to the water, as is the freedom of the outside and inside of the heating surfase from soot and scale.

As an illustration of the effect of the rapid removal of these steam bubbles, the varied results obtained from loco. boilers when fixed on land and when running on rails may be cited. In Mr. Bryan Donkin's book, previously referred to, a number of tests from loco. boilers is given.

Comparing two tests showing the same efficiency 70 per cent. In the loco boiler on land there were 2·6 sq. ft of heating surface per lb. of coal burnt per hour, and the evaporation worked out at 4·0 lb. water per sq. ft. of heating surface per hour, while, on the running loco boiler, there were 1·1 sq. ft. of h.s. per lb. of fuel burnt per hour, and the evaporation 10 lb. water per sq. ft. of h.s. per hour. It will be seen that on the running boiler the effectiveness of the heating surface was more than doubled, and this may be ascribed to the vibration of the loco which accelerated the removal of the steam bubbles.

The position of the feed pipe should be such that the water moves in the reverse direction to the hot gases, in order to get a low flue temperature, and any sediment in the water should, of course, be deposited where the temperature is lowest.

It is highly necessary that the tubes over the fire have a perfectly free and unchecked circulation, so that there is every facility for the immediate discharge of steam from the top of each tube, and ample provision for a supply of water at the bottom to take the place of the steam formed. This is especially desirable where the boilers are liable to be forced, and if these principles are correctly carried out in the design it is impossible to have steam "pocketted" in the tubes, which might cause an accident through over-heating.

In addition, a free circulation is necessary to prevent "priming," often caused by the intermittent discharge of steam where this is defective. Priming is also liable to occur where the water surface at the water level is restricted. A very violent ebullition is set up by the rapid discharge of steam through the water in the steam space, and to diminish this as far as possible, ample steam disengaging area should always be allowed.

The heating surface of the boiler should be arranged to split up the hot gases as far as possible, and for this reason it is likely to be more effective when intersecting the path of the gases than when running parallel to it. In the Lancs. boiler the proportion of heating surface to grate area is usually about 28 to 1, in the water tube boiler about 50 to 1.

There are very many water tube boilers on the market which may roughly be divided into two classes:—

(1) The vertical tube class.
(2) The horizontally inclined tube class.

From among the best known in the first class the "Yarrow," "Thorneycroft," "Cahall," and "Stirling" may be mentioned, and may be said to be of the "free circulation" type, in that they have each of the tubes separately and independently connected at their upper end with the steam drum, and at their lower end with a solid feed space.

In the second class, which includes the "Belleville," "Babcock and Willcox," "Niclausse," Durr," etc., the circulation is somewhat restricted inasmuch as the feed does not quite directly find access to the

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bottom of the tubes neither does the top end of the tube connect directly with the steam space.

Turning to the particular type of water tube boiler which the author is trying to supplant, the drawing this evening. It will be noticed that the Stirling boiler consists essentially of three steam drums and two mud drums connected by four main banks of tubes. The tubes, 3½in. diam., are of weldless steel, and are simply expanded into the drums. They are all bent to the same radius being curved at each end so that they enter the drums radially.

The front and the central steam drums are connected both above and below the water level, while the central and back steam drums are connected above the water level only. The two mud drums are connected together.

The three steam drums are carried by a steel framing and from them the water drums are suspended. These are kept quite clear of the side walls and foundations, so that they are free to rise and fall with the expansion of the tubes. In practice these drums drop about ¼in. from their position when cold. Another point to be observed is that owing to the spring in the curved tubes, any tendency there may be to unequal expansion in the some bank of tubes, does not lead to leaky joints.

The feed water enters the boiler at the back steam drum, at a part most remote from the fire, and since there is no under-water connection with the central steam drum, its passage must necessarily be down the last bank of tubes, where it is gradually heated up, causing most of the scale to be deposited, the sediment falling into the rear water drum. The water in the front section over the fierce heat of the fire is thus left clean, and the life of the tubes greatly prolonged thereby. This arrangement of the feed enables water to be used which, under ordinary circumstances, would be quite unsuitable for tubulous boilers.

Owing to this construction the circulation is practically perfect, as the tubes are nearly vertical and each has a free outlet into the steam drums. In the horizontally inclined type of water tube boiler, the tubes are certainly straight so far as cleaning is concerned, but considered from the point of view of circulation, the Stirling boiler has a distinct advantage, since there are no right-angle turns, due to headers, &c., that have to be negotiated.

The circulation may easily be followed in the working model with glass tubes, which will be under steam shortly. Its path, of course, varies slightly with conditions of firing. When working up to full power all the tubes in the first bank are uptakes, and also the first row in the second bank; the remaining tubes in the second bank and all those in the third bank are downcomers. The circulation in the back bank of tubes is slow and only depends upon the difference in temperature; cold feed coming down the last two rows and the hotter water rising from the mud drum in the front two rows.

It will be noticed that from the very nearly vertical position of the tubes, an exceedingly large combustion chamber is obtained. Other points to be noticed are:—The tubes are "staggered" and thus split up the hot gases as far as possible. The two mud drums give an exceptionally large water capacity for this type of boiler. Any tube may be cut out and replaced without the removal of any other tube or a disturbance of the brickwork To test the facility with which this operation can be carried out, a trial was made in the presence of an independent engineer, in which a tube, selected by him as being the most difficult to remove, was cut out and replaced within an hour.

All the surfaces subject to pressure are cylindrical.

Its construction is an ordinary boilermaker's job, and there is no elaborate machine work about it, screwed joints, &c. which are liable to give trouble when subjected to the action of hot gases.

There is a large steam disengaging area, but as an extra precaution against priming a diaphragm is fixed across the middle steam drum near the top. The steam, after leaving the front drum, passes into the middle drum below this diaphragm, and so to the back drum, where the water surface is quiescent; from here it returns to the middle drum, but in this case is led into the space above the diaphragm, over which the stop valve is fixed.

The boiler is remarkably free trom any tendency to prime, and many cases could be cited in which, while being forced to nearly double its designed evaporation, the percentage of moisture in the steam was negligible. As an instance, the designed evaporation of the boiler is 4lbs. of water per square foot of heating surface per hour. A test was made by Professor Ewing on the Stirling boilers supplied to the Brompton and Kensington Electric Supply Company in order to show the maximum evaporation that could be obtained with forced draught. This worked out at 7·4 lbs. water per square foot of H.S. per hour, or nearly double the normal capacity, and the amount of moisture in the steam was only ·063 per cent.

With regard to the cleaning, at first sight the curvature at the end of the tubes may appear to offer difficulties, but in practice it is found that this is not the case. For soft scale a steel scraper attached to a chain is drawn through the tubes, and for harder scale the Turbine Cleaner, already described, may be used with advantage. There is no difficulty in following the curve of the tube as this is struck to a large radius. The action of the scraper aud turbine, working in a curved tube, can be well followed from the illustrations now shown on the screen.

As an example of the ease with which tubes may be scaled by the Turbine Cleaner, the Author was recently informed by the engineer of a large steel works in Sheffield that at the end of a six months' run, three men with a turbine are able to thoroughly clean a Stirling boiler of a size equal to two 30 by 8 Lancashire boilers in one day.

Stirling boilers are also made with three steam drums and one mud drum for marine work, and for use where space is restricted; and again with two steam drums and one mud drum for small powers. About 2½ million h.p. of Stirling boilers are now in use throughout the world.

If there is one particular service more than another in which the water tube boiler is able to prove its superiority over older types, it is when working in conjunction with the waste heat from puddling and re-heating furnaces, &c., on account of the large heating surface that can be compressed into a very small space. The next two slides will show you an arrangement of Stirling boilers in this service. It will be noticed that the first is fixed over the top of the furnace to economise space. Ten boilers similarly fixed have been supplied within the last twelve months to a large steel works in Scotland. The boilers from which Tests Nos. 2 and 3 are taken, were planted at the back of the furnaces, with a short connecting flue from the neck of the furnace to the boiler.

With regard to the tests given at the end of this paper on boilers fired with waste heat:—

No. 1 represents the results from a Cornish Boiler fired with waste heat from a Tube-welding Furnace in this district. It is interesting to compare the evaporation per lb. of coal on this boiler with that shown with Stirling Boilers.

Nos. 2 and 3 were taken from Stirling Boilers working from puddling furnaces in the Leeds district. They are fired with Yorkshire slack, and a steam jet blower is used.

No. 4 is from a steel re-heating furnace using slack and fitted with a steam jet blower.

There is no question that where waste heat is available and is properly applied, the steam engine is an exceedingly economical prime mover.

At a Tube Works in this district, with which the author is connected, the waste heat from the tube furnaces generates steam in two Cornish boilers. There is a horizontal condensing engine indicating 90 h.p. on the average, and two smaller non-condensing engines of about 25 h.p, For the last twelve months the power cost worked out as follows, taking fifty weeks at 54 hours per week on the basis of 80 B.h.p.:—

Wages	·139d. per B.H.P. hour.
Fuel	·097d. „
Stores	·056d. „
Depreciation & Upkeep	·075d. „
Total ...	·367d. per B.h.p, hour; or £4 5s. 0d. per B.h.p. per annum

One of the boilers is arranged for hand firing if required. When both furnaces are on the hand firing is not needed. The figure given for fuel covers the cost of the slack fired when the furnaces are off

The wages item includes a proportion of the works foreman's time for supervision, and the fitter's time on repairs, etc., in addition to the driver's time.

The above figures will indicate that, where full advantage is taken of waste heat, even the out-of-date plant can make a very good show in working costs, and, so far as reliability is concerned, it may be remarked that in this particular case the main engine has already run for forty years without mishap, and there seems no particular reason why it should not run for another forty if required.

By this it is, of course, not intended to advocate the use of obsolete plant generally, but merely to point out that under certain circumstances, where heat is obtained as a bye-product so to speak, no very appreciable saving could be made in power cost by adopting the most up-to-date plant; and there are a very large number of works in this country with such a source of power available which is either not used to its full advantage or else neglected altogether, and slack goes under the boilers while flame goes up the furnace stacks.

It must not, however, be supposed that in future the sphere of steam will extend no further than to utilise waste heat or patch up obsolete plant, and experience alone will show whether the gas engine is as free from breakdown, reliable, and as well able to bear widely fluctuating loads as its older rival.

There is no doubt that the gas engine, with its thermal efficiency twice that of the steam engine, looks very well on paper; but, after all, the cost sheet is the fairest comparison, and there seems very little difference between using 1lb. of anthracite at 22s 6d. in the one case, and burning 3lbs. of slack at 7s. 6d. in the other, the cost of plant being approximately the same in each case.

In short, it is highly probable that efficient steam plant will continue to hold it own in a great number of directions, until both gas and steam are superseded by some method of converting heat into electrical energy without the employmenf of a mechanical medium.

NOTES ON WATER SOFTENING.

The question of water softening is somewhat complicated, and to enter into the subject fully is beyond the scope of this paper. The following brief remarks may, however, be of interest in a district where the water supply is on the whole very indifferent in quality.

Very many types of water softening apparatus are on the market, and some of them give excellent results when the adjustment of the reagents and cleanliness of the filters receive proper attention.

[illegible]

[illegible]

[illegible]

The illustration now shown on the screen represents such an apparatus for the thermal purifying of feed water. It consists of a cylindrical tank, strong enough to carry the same pressure as the boiler. A system of iron trays is fitted in the upper portion of the tank, and so arranged that the feed water shall pass over them seriatim. Live steam is admitted towards the top of the apparatus and rapidly heats up the thin films of water passing over the trays. Most of the deposit takes place upon the trays, and these can be lifted bodily out of the apparatus for cleaning purposes. The lower portion of the tank serves as a settling chamber for any sediment that is washed off the trays. As will be noticed, the outlet for the feed is placed some distance off the bottom, so that this sediment is not carried into the boilers.

By enlarging the settling tank, the advantage of a thermal storage chamber is secured, and a quantity of hot feed water can be accumulated when the demands for steam are low.

To prevent excessive radiation, a good non-conducting covering for the apparatus is, of course, necessary, and with this the heat loss will be practically negligible, about ·2 B.T.U. per square foot per hour per degree difference in temperature of steam and air.

It is usual to fix the purifiers above the level of the water in the boilers so that the treated water will feed into them by gravity. Where this arrangement is impossible, two feed pumps must be employed, one pumping into and the other out of the purifier. If exhaust steam be available it may be used with advantage in conjunction with a feed heater for the preliminary heating of the water before it enters the purifier.

The apparatus just described has been designed to give a very large depositing surface in the minimum of space, combined with facilities for easy cleaning. A serviceable purifier can however, often be constructed at very small expense if a large tank is available that will carry the steam pressure. This can easily be fitted with a series of depositing trays, which should be arranged so that the water shall be exposed to the action of the steam for as long a period as possible.

At some works near London, where a home-made purifier of this type was in use, the period between boiler cleaning was able to be extended from seven to twenty-one weeks.

The introduction of composition, disencrustants, etc., into any boiler is to be deprecated, In many cases more harm than good is done. Chemical action certainly takes place, but the formation of new salts cannot compensate for the increased quantity of solid matter introduced into the boiler. If any treatment be adopted it should always be a treatment of the water previous to its introduction into the boiler, and no chemical agent should be used in the boiler itself except in the case of it being off for cleaning. Where hard scale is formed and has been

allowed to accumulate, the cleaning of the boiler may be very greatly facilitated by the use of caustic soda. The boiler should be let down and a quantity of caustic soda (from 1 to 2lbs. per 100 gallons of water) introduced through the man-hole. The boiler should then be got under steam again and kept at about 60lbs. pressure for five or six hours. It must be allowed to cool down gradually, not blown down, and when it is cool enough to work in, the water may be run off and the scale removed while it is wet. It will be found that where the scale is too thick for the caustic soda to penetrate, this will have worked its way between the boiler plates and the scale, which will be so thoroughly loosened that it will come away in flakes.

As an instance of the utility of caustic soda, the case of an installation of Stirling boilers in Yorkshire may be quoted. Here the water was bad, containing from 30 to 40 grains of solid matter per gallon. An apparatus for the chemical treatment of water, which had been made by the firm in question, was in use, but this did more harm than good. The water was never allowed to settle in the softening tanks, and the precipitated matter, together with the reagents used (lime and soda) were lying to a depth of some feet at the bottom of these tanks. This resulted in an enormous quantity of scale-forming solids, chiefly lime, being taken into the boiler in addition to the already large proportion of solids contained in the water.

The boilers had been absolutely neglected, and in a great number of the tubes there was only a 1in. waterway, and a few of them were entirely choked. A caustic soda treatment similar to that already described was adopted, and with the aid of a turbine cleaner the tubes were entirely freed from the last trace of scale. Much of the deposit had been so thoroughly loosened that it fell out of the tubes in "casts" and was found lying in the mud drums on opening up the boiler.

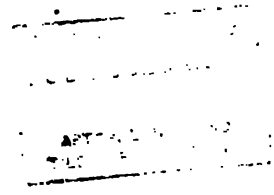
RESULTS FROM BOILERS WORKING WITH WASTE FURNACE HEAT.

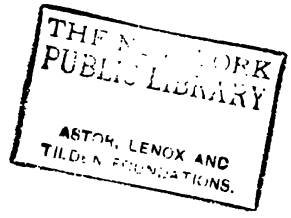
	1. Cornish Boiler and Tube-welding Furnace.	2. Stirling Boiler and Puddling Furnace.	3. Stirling Boiler and Puddling Furnace.	4. Stirling Boiler and Reheating Furnace.
Duration of Test in hours ..	Mean of 3 1 hr. trials	24	24	12·42
Heating Surface of Boiler in sq. ft.	510	1,710	1,710	1,440
Grate area of Furnace in sq. ft. ...	14	10 5	10·5	—
Ratio: Heating surface to Grate area	36·5 to 1	162·8 to 1	162·8 to 1	—
Total Coal used in lbs.	660	12,404	11,760	7,740
Coal used per hour in lbs. ...	660	520	491	621
Total Water evaporated in lbs. ...	1,710	93,310	94,170	46,640
Water evaporated per hour in lbs.	1,710	3,890	3,920	3,240
Water per sq. ft. of H.S. per hour	3·36	2·27	2·29	2·62
Average water per hour per lb. of Coal	2·6	7·52	8·0	6·05
Temperature of Feed in Fahrenheit	50°	139°	153°	56°
Temperature of Flue Gases in Fahrenheit	—	379°	390°	498°

No. 1 represents the results from a Cornish Boiler fired with waste heat from a Tube-welding Furnace at Great Bridge. Fuel: Large Coal.

Nos. 2 and 3.—Tests from a pair of Stirling Boilers working from Puddling Furnaces near Leeds. Fuel: Yorkshire Slack and Steam Jet draught.

No. 4.—Test from a Stirling Boiler and Steel Re-heating Furnace. Fuel: Slack and Steam Jet draught.

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TILDEN FOUNDATIONS.

THE DISCUSSION.

THE PRESIDENT: Many years ago, when gas was introduced, it was thought that there would be no further use for candles, and it has also been predicted that electricity would to a great extent supersede gas, but experience has taught us otherwise; in fact the demand for both candles and gas has somewhat increased. We can then, I think, reasonably expect that although as a motive power, gas engines will supersede steam engines, many other purposes will necessitate the employment of steam boilers, and a comparison of the numerous designs at present in the market is interesting.

I have made exhaustive tests of water tube and Lancashire boilers, and whilst for some purposes the former design is very applicable, there are many instances where Lancashire boilers and even Cornish boilers may be used with greater economy and advantage.

The practical illustration of a Stirling boiler, which Mr. Tarbolton has given to us, does not demonstrate the troubles which in many instances are experienced with tubular boilers.

This boiler has one very good feature, viz., that the flame is conducted longitudinally along the tubes, and the advantage of this detail, as compared with a boiler where the flame only crosses the tubes transversely, is, I think, very evident, but against this there is the difficulty of cleaning the tubes, and the tendency to become loose in the drums by expansion.

The cleaning tool which has been submitted for inspection, appears to me quite capable of removing all the scale, but I cannot see how it may be used without considerable damage to the tubes.

I can mention many cases where costs have been increased by substituting a tubular boiler for a Lancashire boiler, and where the demand for steam is very intermittent, the employment of a tubular boiler should be undertaken with a great amount of caution.

Water may be evaporated very rapidly in a tubular boiler, and if this be the only consideration, it may be done at infinitely less cost than in a Lancashire boiler, but the latter has the great advantage of being able to store more steam, which is very necessary in so many instances, more particularly, perhaps, in iron and steel works.

Mr. JNO. W. HALL: I have been very much interested in the very excellent paper we have had to-night, and with the capital way in which it has been got up. Great credit is due to Mr Tarbolton for the manner in which the subject has been presented, including the excellent views. This boiler is interesting because it works on the scientific principle of counter currents. You will see that the products of

combustion travel from right to left, while the water is travelling from left to right. The effect is that the hottest gases always meet the hottest water, and the coldest gases the coldest water, which is the condition for securing maximum efficiency. Now I notice that Mr. Tarbolton has called attention to the experiments in Mr. Bryan Donkin's work, and says that from 107 tests of Lancashire boilers the efficiency worked out at 62·4 per cent. Unfortunately there was not an equal number of tests made upon the water tube boilers, but those headed the summary of averages with an efficiency of 77·4 per cent. I think, however, that that statement needed a little qualification. In the first place the Lancashire boilers varied enormously—because they were some of them poor examples, and were not all worked with maximum efficiency. The tubular boilers were of modern design and generally well looked after, and Mr. Donkin himself speaking of these tests says in his book (I have brought an extract from it to read to you) :—

> "They are of more value than theories, and one of the chief inferences to be drawn from them is that by varying the working conditions, the efficiency of any given type of boiler may come out sometimes higher, sometimes lower, than is shown in the tables. When making these summaries, the author at first thought that he might be able to draw from them the conclusion that some one type would prove to be more economical than another. In view of the great variety of working conditions, and great range of evaporation in lbs. of water per square foot of heating surface per hour, this inference does not seem possible. From these collective experiments it is quite clear that much more depends upon how a given boiler, of whatever type, is worked, with clean or dirty surfaces, good or bad combustion, etc., than upon its form, internal or external fires, water or smoke tubes, or the particular way the differently shaped heating surfaces are presented to the furnace and hot gases. In other words two boilers, totally dissimilar in form and type, will generally give about the same efficiency if worked properly, at about the same rate of evaporation, with equally clean surfaces, and not forced."

Now in Lancashire boilers the heating surface is usually about 28 times the grate area, and in the tubular boilers it is about 50 times. Obviously the boiler which has the larger heating surface must be the more efficient. Sometime ago I had to advise in two instances as to putting in boilers, and I sent out inquiries and asked for prices and particulars simply giving the makers the quantity of water that had to be evaporated. I may tell you that the heating surface allowed by the makers for the same work in the water tube boilers varied from 22 to 44 per cent. more than in the case of the Lancashire boilers, and the cost of the water tube boilers ran from 35 to 53 per cent. more than the Lancashire, and I was pretty well satisfied that there would be an efficiency as guaranteed by the makers of 15 per cent. more in favour

of water tube boilers over the Lancashire type under such conditions. The ratio of heating surface to grate surface varied from 52 to 81 per cent. more in the case of the tubular than in that of the Lancashire boilers. It must nevertheless be admitted that where the work is intermittent, the tubular boiler, as a rule, is not an efficient tool. I know a case where we had tubular boilers in, and directly we started the steam hammer almost all the water went out of the boilers, and the pressure went down to next to nothing. When the place was stopped at meal times the steam was screaming away from the safety valves in a very short time, and the manager drove the poor old firemen nearly crazy, and the men left. They had fresh firemen, but things were no better, and in the end the boiler was taken out, and a Galloway boiler put in. So if you have intermittent work you must be very careful what type of boiler you adopt, although these tubular boilers are being used successfully for various purposes. But what we should most like to know is what are the relative wearing powers of the two boilers. The life of a good Lancashire boiler is like the life of an old woman, the Lord knows what! They have lasted for a generation or more, while I know of a case in which a tubular boiler was taken out, worn out in 18 months, but that was hardly a fair case because the water was not suitable. The fact of the matter is that if you want the highest efficiency in water evaporated per lb. of coal burnt it does not make a great deal of difference whether you use a tubular boiler or whether you use a Lancashire boiler with an economiser, and I am very doubtful at the present moment which is the best to do. There is one point in favour of the tubular boiler, namely, the better conditions for combustion afforded by it as compared with the flue in a Lancashire boiler. The slack of this district is of a bituminons character, and therefore burns better in a larger combustion chamber which is not so necessary when burning Lancashire slack. I have often been struck with the difference between fires in Lancashire boilers in the Midlands and in the North of England, the latter burning so much brighter. I have one works here under my charge in which are Lancashire and water tube boilers working side by side into the same chimney. The fires in the confined spaces of Lancashire tubes are very dull compared with those in the large combustion spaces of the water tube boilers, showing very clearly which are burning the coal to the best advantage. There is an opening for boilers of the water tube type provided that the water is good and that the work is regular. If those conditions are fulfilled, then tubular boilers are satisfactory, if they are not, then they are unsatisfactory.

Mr. H. SILVESTER: I have been very interested in the paper read to-night, and have obtained a considerable amount of information on the various types of the class of boiler described in the paper.

Some years ago I read a paper on the "Chemistry of boiler incrustation" before this Institute, and I was glad to hear Mr. Tarbolton

condemn the use of compositions and recommend the softening of the water before it enters the boiler, which is the only reasonable method of dealing with the scale forming substances in the feed.

As regards the particular form of apparatus described in the paper for heating the water, I believe the principle was tried in a number of South Staffordshire boilers a few years ago. The idea was that the bulk of the gypsum would be largely precipitated at a temperature of 260°F., and the feed water was therefore in the first instance allowed to fall into a receiver contained in the boiler, where the mineral matter would be precipitated and collect. I do not think the apparatus was a success, as the scale forming substances, though largely precipitated, were carried along with the feed and scaled.

In the example of water softening given by the adoption of this method in an outside receiver, I notice that there are 16 grains per gallon of sulphate of lime still left in the treated water, and I should like to ask Mr. Tarbolton if this is not an excessive amount for a water to contain that is to be used in his boiler? Would it not be economical both as regards fuel consumption, and life of the tubes, to reduce the hardness to some 4 or 5 degrees by one of the well-known water softening plants?

Mr. THOS. WILLCOX: As regards this water-tube boiler I may say we have just got one in on test—a Cahall boiler—and we find so far that it does about the same as an ordinary Cornish boiler. That is about all we get out of it, and I am afraid we shall have a lot of trouble with the scaling in the tubes. We tested a Cornish boiler some time ago and it came out at about 4½lbs. of water per pound of fuel, and we obtained about the same result when we used a Stirling water tube boiler in connection with a mill furnace. I am interested in the paper, and very much indebted to the reader for the information he has given.

Mr. JNO. FELLOWS: I have no practical knowledge of these boilers, for I am not an engineer nor a chemist. I put down a Cornish boiler this week, and it seems to be going on very satisfactorily. I should be afraid that the apparatus for cleaning the tubes would either damage the tubes, or that on the other hand you could not tell whether the tubes were cleaned or not. whereas in a Cornish boiler you would soon see whether the men had done their work and cleaned the boiler properly.

Mr. TARBOLTON: First, with regard to the points raised by Mr. Toy. The cutters revolve, and there is no sliding or cutting action on the internal surface of the tube whatever. The cutters have a percussive or tapping action on the scale, and that loosens it. As to distorting the tubes, it is the first time I have ever heard of anything of the sort happening. The scraper springs to a certain extent, and the amount of pressure you could get on to the tube would not injure it. Another

point raised by Mr. Toy was that the expansion and contraction might tend to loosen the tubes, but if you refer to the diagram, showing in full size the method of expanding into the drums, you will notice that the tubes are slightly burred over inside, and the greater the pressure the tighter is the joint made between the tube and the drum. Also the holes are reamered out from the inside, there being a slightly larger diameter inside the drum than outside, so that the tendency is always to increase the tightness of the joint. Both Mr. Hall and Mr. Toy have referred to the unsuitability of water tube boilers for intermittent work, but for such work as steam hammers, for instance, they have answered well. I do not know whether in the case Mr. Hall mentioned the boilers were working at the ordinary pressure, say, 40lbs. [Mr. HALL: Yes, 45 if I remember rightly.] Because for such work as steam hammers it is advisable to work at the normal pressure of the boilers, say 160lbs, and then reduce to the desired pressure. By reducing you get the required reserve of steam, and also slight superheat. Mr. Hall mentioned the countercurrent and its advantages. I am much obliged to him for pointing that out. I did not refer to it as strongly as I might have done in the paper. With regard to the remarks of Mr. Bryan Donkin, quoted by Mr. Hall, I think the best way to look at the argument of efficiency is to notice what guarantee the makers are prepared to give. With the "Stirling" water tube boiler a guarantee of efficiency of 75 per cent. will always be given, but I do not think you could get any such guarantee as that with a Lancashire boiler. Of course, as Mr. Hall pointed out, the tests in Mr. Bryan Donkin's book were taken under all sorts of conditions, and as he rightly says, this makes a very great deal of difference on the results obtained. When firing the boilers light you naturally get so much higher efficiency than when working at a high load. He also mentions that the life of a water tube boiler is not as long as a Lancashire boiler. Water tube boilers have not been in general use for very long, so it is difficult to get correct ideas of their life, but the drums in a water tube boiler would be likely to wear considerably longer than the flues in a Lancashire boiler, because they are not in actual contact with the flame. As to the renewal of tubes, that depends upon the treatment the boiler receives. If the tubes are cleaned, say every six months, and treated properly their life is certainly very considerable. We have examples of boilers running in which the tubes (I am speaking of the front bank of tubes exposed to the greatest heat) have not required to be renewed for seven or eight years. There is a certain amount of care required with the feed water, but this question should always receive attention, whatever type of boiler is used. Any oil should always be eliminated. Mr. Hall also mentioned the large combustion chamber. This very large combustion chamber is, as he says, the very thing that is required for the bituminous slack of this district. Mr. Silvester raised the question of sulphate of lime in feed water, and in reply to his enquiry I may say that 16 grains to the gallon is more than

is desirable. Such water can be used, but the tubes would have to be cleaned out every three months. There is, however, a good point about this thermal purifier which should not be lost sight of. The mineral constituents of feed water often vary very considerably from time to time, and where such feed water is high in sulphate, it is very useful to get down that sulphate to a definite amount so that the correct proportion of soda ash can be pumped into the feed for its treatment. Mr Willcox has mentioned that a water tube boiler of the "Cahall" type, fired with the waste heat from a furnace, has been put down at his works. Without knowing the exact conditions it is difficult to give an opinion as to why it does not get more steam than the original Cornish boiler. He also stated that the evaporation was about 4½lbs. of water per pound of coal fired in the furnace. The list of tests given at the end of the paper show an evaporation of 7 or 8lbs. with Stirling boilers in similiar service.

In conclusion, I beg to express my deep appreciation at the honour of being invited to read a paper before this Institute, and wish to thank you very heartily for your kind attention this evening.

THE PRESIDENT: We all appreciate Mr. Tarbolton's efforts to describe the merits of the Stirling boiler, and these papers are always more interesting to us when illustrated practically. We know the great trouble entailed in preparing a model and lantern slides, and therefore I have very great pleasure indeed in proposing a hearty vote of thanks to Mr. Tarbolton for his very interesting and useful paper.

Mr. PIPER seconded the proposition, which was carried.

Several members closely inspected the working model, and Mr. Tarbolton explained its action.

The Sixth Meeting of the Session was held at the Institute, Dudley, on Saturday, February 18th, 1905.

THE PRESIDENT (Mr. H. B. TOY) presided.

The minutes of the last Meeting were read, approved, and signed.

Messrs. David Freeman, Edward Houghton, and W. G. L. Riddle were elected members of the Institute.

Mr. O. F. HUDSON, A.R.C.S., then read the following paper, which was illustrated by a series of lantern views.

THE MICROSTRUCTURE OF CAST-IRON.

By O. F. HUDSON, A.R.C.S.

Of the three great classes of iron, cast-iron is the most impure; it never contains less than 2 per cent. of impurity, and may contain as much as 10 per cent. Of these impurities carbon is an essential constituent, as upon the amount and mode of existence of this element depend the distinctive properties of the several classes of the metal, the other impurities being of importance principally according to their effect on the relation between the carbon and the iron. Thus silicon and sulphur are in this respect of the utmost importance in determining the grade and quality of cast-iron. The effect of silicon is to produce a grey soft iron by its tendency to cause the separation of graphite and to reduce the amount of combined carbon. Sulphur, on the other hand, tends to make the iron hard and white because it prevents the separation of graphite and correspondingly increases the amount of combined carbon.* The ratio of graphite to combined carbon is the most important factor in determining the grade and quality of cast-iron, since metal containing a constant total amount of carbon may, by varying this ratio, be made to assume all varieties from white to very grey iron.

In considering the microstructure of cast-iron the following constituents formed by iron and carbon must be recognised:—

Ferrite, or pure iron, is soft, ductile, and is not stained by the usual etching agents. Careful and fairly deep etching will show very clearly the boundaries of the crystalline grains.

Cementite, the carbide of iron, corresponding to the formula Fe_3C is hard and brittle, and also unstained by etching agents.

Pearlite, an intimate mixture of cementite and ferrite is distinguished under the microscope by its characteristic banded structure, and consists of very thin interstratified plates of cementite and ferrite. Steel containing ·9 per cent. of carbon is made up entirely of pearlite.

* Turner, "Journal Iron and Steel Institute," 1886, p. 163.

Graphite, pure or almost pure carbon, and commonly occurs as large curved flakes. The average size of the flakes varies in different kinds of iron, and it may occur in the form of very minute grains when it is known as temper carbon or temper graphite.

It will be noticed that ferrite and cementite may occur as separate constituents or in intimate mixture as pearlite. In the former state they may, when necessary for the sake of clearness, be distinguished by the terms free ferrite and free cementite.

In addition to the above constituents formed by iron and carbon there is one other very important one containing the phosphorus that must be recognised. It is known as the phosphide eutectic, and exhibits the typical banded structure of an eutectic. It is hard, and in the case of grey irons, is usually well developed by polishing alone, and is clearly shown by the usual etching agents. Where, however, it occurs together with free cementite it is only distinguished after heat tinting *

The specimens for micro-examination are taken when possible by sawing a small piece from the metal to be examined. In the case of mottled and white iron such a course is not possible, and the specimen has to be taken by chippings. The specimen may conveniently be of the following dimensions: $\frac{1}{2}$in. × $\frac{3}{8}$in. × $\frac{3}{16}$. One of the large surfaces is then made perfectly plain by filing with a smooth file, and the edges bevelled to prevent tearing of the polishing papers. A smooth-filed, clear, perfectly plain surface having thus been obtained the file marks are removed on fairly coarse emery paper, and the polishing continued on emery papers of increasing degrees of fineness. The final polishing and removal of all scratches is done on chamois leather moistened with a thin paste of the finest rouge, or better with alumina obtained by the calcination of ammonium alum. Alumina is much more effective as a final polisher than rouge, and for cast-iron work is very easly prepared. It is usually recommended for general purposes that the alumina should be ground and graded by careful levigation, and the products made into pastes with the finest Castile soap. A polishing powder that answers admirably for the final polishing of cast-iron may be made by calcining ammonium alum in a porcelain dish in a muffle and lightly grinding the alumina so obtained, the powder being dusted onto moistened chamois leather for polishing.

An examination of the specimen after final polishing, and before etching often gives useful information, *e.g.*, the amounts and relative distribution of graphite and phosphide eutectic in grey phosphoric irons.

In etching specimens of cast-iron there is a fairly wide choice of

* Stead, "Iron and Phosphorus" ("Journal Iron and Steel Institute," 1900, Vol. 2)

reagents that give satisfactory results, but perhaps the most convenient are either

(*a*) a 2 per cent. solution of nitric acid in water or alcohol, or
(*b*) a 5 per cent. solution of picric acid in alcohol.

To avoid misleading results the etching should be conducted with discretion, and the specimen should be examined under high and low powers, the etching being, if necessary, continued further, or the specimen repolished and re-etched. After etching the specimen may, with advantage, be rubbed lightly on parchment covered with a thin paste of precipitated calcium sulphate.

The subject of the constitution of cast-iron is much simplified by the elaboration of and the prominence recently given by Howe*to the view that cast-iron may be considered as steel with, in the case of grey or mottled iron, flakes of graphite scattered through its mass. Very mild steel consists of nearly pure iron, and its microstructure shows practically only one constituent, ferrite. As the percentage of carbon increases the amount of free ferrite decreases, its place being taken by pearlite. With ·9 per cent. carbon the steel consists entirely of pearlite, and with more than this percentage of carbon free cementite makes its appearance as a network enclosing the pearlite. The amount of free cementite continues to increase with increase in the amount of carbon, the pearlite at the same time decreasing, until with about 2 per cent. carbon the material is no longer called steel but becomes white cast-iron. Steels and white cast-iron thus form a continuous series, and microspically there is no difference except one of degree between high carbon steel and white iron. In the same way the various grades of grey iron and mottled iron may be considered as members of the steel white cast-iron series containing more or less graphite scattered through their mass. Thus very grey iron, with its carbon practically all as graphite may be regarded as a mild steel, plus this graphite, and its structure consists essentially of ferrite and graphite. As the amount of combined carbon increases the matrix of the iron may be considered as steel with a corresponding carbon content. In short, grey iron is steel made weak and brittle by the presence of flakes of graphite, and as steel with the lowest carbon content is the softest steel, so grey cast-iron with the lowest percentage of combined carbon is the softest and most easily worked iron. So also grey cast-iron in which the matrix consists entirely of pearlite is the strongest of its kind, just as in the case of steel the maximum tensile strength is reached when the carbon is present to the extent of about 1 per cent., *i.e.*, the steel consists practically entirely

*H. M. Howe, Am.Inst.Mining Engineers, Feb. 1901, reprinted in "Metallographist," Vol. IV., p. 177. (See also "Iron, Steel, and other Alloys," pp. 163 & 431-435.)
"The hyphothesis . . . . is that composition governs properties in the case of "cast-iron in the same general way, and for the same reason as in the case of "steel, mutatis mutandis."

of pearlite. In making use of this analogy it must be borne in mind that the matrix of cast-iron owing to the presence of large quantities of impurities, *e.g.*, silicon and phosphorus, does not exactly correspond to ordinary steel. Mottled and grey irons are therefore more correctly considered as *very impure steels* containing more or less graphite. Although theoretically it is possible to produce every grade of cast-iron from grey to white by physical means alone (such as altering rate of cooling) and without change in chemical composition, it is seldom so practically, the changes usually being brought about by variations in constituents other than carbon. Thus in certain cases, *e.g.*, when the iron contains but little impurity beyond the carbon, white iron can, by very slow cooling from its melting point, be converted into grey iron, and the reverse change made to take place by rapid cooling. But in many cases white iron, even by the slowest cooling, is not made grey, nor on the other hand can some kinds of grey iron be made white by the most rapid quenching. Any sample of white iron can, however, be made grey by increasing the amount of of silicon in it, and at the same time, if necessary, reducing the amount of sulphur, and any sample of grey iron may be made white by reducing the amount of silicon or increasing the amount of sulphur. As would thus be naturally expected the influence of these two elements, silicon and sulphur, on the microstructure of cast iron is very great. It is nevertheless almost entirely indirect (in determining the amount of carbon that shall exist as graphite or in combination) as they do not when present in the quantities found in ordinary commercial cast-iron lead to the presence of new or easily defined constituents. Thus silicon has been shown to exist in cast-iron in the form of silicide of iron $Fe_2 Si$*, but it exists in the state of solid solution in iron, not as a separate constituent, and unless present in very large amounts does not apparently alter the characteristic appearance of ferrite. The name silico-ferrite is sometimes used to distinguish such ferrite from true ferrite or nearly pure iron. It is worth noting here that cast-iron containing about 4 per cent. silicon, when deeply etched and examined under a high power of the miscroscope, shows very clearly that the ultimate structure of silico-ferrite consists of very minute cubes. Such is also the ultimate structure of ordinary ferrite, but in the case of silico-ferrite, with about 4 per cent. silicon, it is much more easily revealed.

Manganese, in the quantity in which it is usually present in cast-iron, does not have any very great influence on the structure. It has a tendency to increase the amount of combined carbon, but structurally it is not identified, as like silicon it is present in solid solution in the iron. An impurity that determines to a great extent the value and suitability of cast-iron for particular purposes is phosphorus. It also has a

* *Lebau Comptes Rendus* CXXXI, p. 933.
See also *Carnot and Goutal, Annales des Mines*, Oct. 1900.

characteristic influence on the structure of the metal. Stead has shown* that iron free from carbon is capable of holding in solid solution as much as 1·7 per cent. of phosphorus, and that a eutectic composition is reached with 10·2 per cent. phosphorus, the eutectic having a melting point of 980° C, and consisting of phosphide of iron (Fe_3P), and iron saturated with 1·7 per cent. of phosphorus. He also shows that carbon throws phosphorus out of solution in iron, and that in grey iron with but little combined carbon the presence of the phosphorus is made evident by the appearance of areas of phosphide eutectic. Such small quantities as ·03 per cent. P may thus be detected in grey iron, and in the case of very phosphoric grey iron, such as Northampton iron, containing about 1·5 per cent. P, this phosphide eutectic is seen to constitute a very considerable part of the metal. The phosphide eutectic in cast-iron has a lower melting point (935° C) than that of the eutectic in iron free from carbon, and it probably has a somewhat different composition due to the presence of silicon and manganese. In the case of iron containing much free cementite, such as white iron the presence of the phosphorus is not quite so evident under the microscope, and requires the aid of heat-tinting to properly reveal it, as it is almost impossible to otherwise distinguish between carbide and phosphide of iron. The phosphide eutectic of such irons is very complex in character, containing phosphide and carbide of iron in the form of plates, silicide of iron and pearlite.

It may be of interest to conclude this paper with a short description of the microstructure of several of the different grades and classes of pig iron.

Considering first hematite iron, which is characterised by its freedom from phosphorus, the microstructure of the No. 1 Bessemer iron is seen to consist of very large flakes of graphite surrounded by ferrite and enclosing large areas of pearlite. In the No. 2 iron the amount of ferrite has decreased, and the pearlite occupies a correspondingly greater area. No. 3 forge consists almost entirely of pearlite and graphite, and when No. 4 is reached free ferrite has practically disappeared, while in No. 5 free cementite is first seen. In the mottled iron the amount of free cementite is considerable, and the graphite, which has been continuously decreasing in size and quantity, is now only seen in small flakes and in patches; the white iron shows only cementite and pearlite.

In the case of Staffordshire mine iron, with a little more that ·5 per cent. of phosphorus, the phosphide eutectic forms a conspicuous constituent. No. 1 shows large graphite surrounded by ferrite and enclosing areas of phosphide eutectic, the amount of pearlite being very small.

* "Journal Iron and Steel Institute," 1900, II., p. 60.

Nos. 2, 3, and 4 have similar structures, the only difference consisting in a gradual decrease in the average size of the graphite, and a small increase in the amount of pearlite. The pearlite is found in the neighbourhood of, and usually surrounding the phosphide eutectic. No. 5 and No. 6 show very decided increases in the quantity of pearlite and smaller graphite.

Derbyshire iron, with about 1 per cent. of phosphorus, has a structure like that of Staffordshire mine iron except that the phosphide eutectic is somewhat more prominent, while Northampton iron, with 1·5 per cent. of phosphorus, shows still more plainly the increase in the amount of phosphide eutectic, and the almost entire absence of pearlite in the greyer members of a phosphoric series of pig irons.

The details of microstructure referred to in the paper are illustrated by the accompanying microphotographs.

THE DISCUSSION.

THE PRESIDENT: All the members who are in any way connected with the iron and steel trades will recognise the value and practical usefulness of the subject which Mr. Hudson has introduced this evening, and we appreciate his contribution the more as he is so closely associated with our much esteemed member, Professor Turner, of the Birmingham University.

Personally I have not had occasion to use the microscope regularly, but the subject of microstructure of pig iron has been so ably and beautifully illustrated this evening, that I cannot help feeling much indebted to Mr. Hudson.

Those of us who are engaged in foundries or steel works must, I feel sure, be convinced that the microscopic examination and testing of material will be more generally adopted in the future The practical advantage in this method of testing is very great. It has hitherto been a custom of the pig iron makers not to afford consumers very much information regarding the composition of their pig iron, at least where forge and foundry iron is concerned, but I am pleased to learn that some of the makers of the best class of iron are looking more carefully into the chemical composition of the materials employed, although I think even yet they could go a little further with advantage, as in some cases they judge the quality only by the silicon, phosphorus and sulphur. In my own experience I have often found it to be of very great service when the amount of combined carbon, graphite, and manganese are determined.

All who are concerned with the foundry trade have often felt the need of some ready method by which the quality of iron may be ascertained from the appearance of the fracture, as analysing occupies considerable

time; the microscope therefore appears to me the one thing very much needed.

PROFESSOR T. TURNER: I am glad to be here to-night to have had the opportunity of listening to my colleague, Mr Hudson, upon his giving an account of his experiments into the microstructure of cast-irons I can testify from personal observation to the length of time he has devoted to his subject, as also to the care and skill which he has devoted to it. The Institute may congratulate itself upon having had this important metallurgical matter treated to-night with a completeness and detail that it is impossible to find in any of the text books. We have had laid before us, and illustrated on the screen, the results of a valuable series of experiments and investigations into the exact composition and character, as revealed under the microscope, of a series of cast-irons well-known to most of us in the way of everyday trade and manufacture. The conclusions which we shall be able to draw from such investigation will, some of them, prove of the greatest possible use. Some members of this Institute may have noticed that a recent speaker in Glasgow made bold to characterise the application of the microscope to the examination and scrutiny of steel as a failure. I do not think that that expression of opinion will meet with general acceptance from iron and steel men, even in respect of steel. And, I am quite sure it will not in regard to cast-iron. In this field of metallurgy at any rate, the microscope has already, and will still more in the future, prove a great success. This will be readily recognised even if we appeal only to the saving of time effected by the newer method of test, compared with the older system of analysis in the laboratory. By the present method, in the brief period of say ten, fifteen, or twenty minutes, it is possible to take a sample of cast-iron, and to machine it and polish it sufficiently to enable a successful examination to be conducted with the glass. I refer now to an examination conducted at the comparatively low powers that have been used for the majority of the photographs which have been shown by Mr. Hudson. The Institute would be surprised how, when a few general principles guiding an examination are known, the suitability of any particular iron for a definite purpose can be determined with ease and rapidity. The advantages they conferred upon ironfounders and others in making their mixtures will be self-evident. The whole science is a valuable advance in the study and pursuit of metallurgy, especially as I have observed, in connection with iron manufacture *per se*. We have seen revealed on the screen to-night in much detail many of the most surprising facts associated with the composition of cast-irons. To some extent the same knowledge may be gathered from a careful study of the plates attached to the paper. In the first place we see, as Mr. Hudson has been careful to mention, that in grey cast-iron the graphite forms the outside of the area, *i.e.*, the graphite forms first. Inside this area is the ferrite, coming close to the graphite itself. Next in order is the pearlite, as being still more fusible, and consequently solidifying later. If there is any

phosphorus in the iron under examination the position of that is yet further on the inside forming the phosphorus eutectic. As to graphite, the size of this ingredient will be found under the microscope to vary with the number of the iron under experiment. It is a fact which it would be well to bear in mind, that, so long as the experimenter keeps to the same magnification, it is possible to read the number of the pig merely by observing the size of the graphite. It should be recollected also, that the state of the graphite is regulated to some degree by the purity or otherwise of the metal from which it separates, and therefore varies according to that same circumstance Mr Hudson has demonstrated that in respect of ferrite in cast-iron, although it may contain manganese or silicon it always preserves its characteristic and peculiar appearance. When the specimen under treatment is etched and then highly magnified, an ordinary cubic structure is presented to view. I need say little more, I think, regarding the pearlite, except to emphasise that the microscope clearly reveals and establishes that cast-irons containing the maximum proportion of pearlite give the maximum tensile strength. Ironfounders in particular will do well to bear this in mind; they are always peculiarly interested in the phosphide eutectic of the irons with which they have to deal. By the aid of the microscope we can tell at a glance, approximately, the proportion of phosphorus in any pig. We can also give correctly the strength of the pig in which it is found, and the brittleness of the metal can be particularly read and told. In white irons, where of course carbon exists as carbide, the phosphorus will also be found present in the form of solidified solution. In white irons the phosphorus is not thrown out as in grey irons—it remains in the mass. The difficulty, therefore, presents itself that in white irons we cannot ascertain the proportion of phosphorus by inspection. I will turn for illustration of my meaning, so as to make it quite plain, to the plates which accompany Mr. Hudson's paper If you compare Fig. 2 with Fig. 5, both Distington pearlites, and both plates produced under the same power of magnification of the specimen treated, but Fig. 2, a Bessemer iron, and Fig. 5 a No. 3 forge iron, you will recognise a distinct, indeed a great, difference in the size of the graphite contained in the compositions. Now Fig 2 is a No. 1 Bessemer iron, and Fig. 5 is a close-grained forge iron. Those you will notice are pure irons The same difference in graphite appearance is realized from a comparison of, say, Fig. 14 with Fig 15. Both are practically the same brands—Derbyshire (Sheepbridge), but the Nos. differ, Fig. 14 being No. 1, and Fig. 15 No. 3. Practically also the same magnification of specimen has been employed in the making of the plates. Yet, there is quite an enormous difference in the size of the graphite revealed in the two plates. Or I will take as a further illustration the concluding two plates except the very last. I refer to plates Nos. 16 and 17. A different class of irons to the last is covered by these figures. They are Northampton irons—Islip. Fig. 16 is a No. 2 Northampton pig, and Fig. 17 is a

glazed pig. Yet here again the size of the graphite is extremely different in the two plates. I cannot sit down without again expressing, not my own alone, but what I am sure is also the Institute's indebtedness to Mr. Hudson for the great pains he has taken in presenting this subject before us in so interesting a manner, and in illustrating it with such really splendid photographs. Those who have not given much attention to the study of the microstructure of cast-iron before will have learned a good deal from listening to Mr Hudson's able paper.

Mr. W. J. Foster: I do not know that I have very much to communicate on this very important and interesting subject. I came in late, and, unfortunately, not having had an opportunity of previously reading the paper, I am placed at a great disadvantage, but there is one very important point upon which I should like to offer a suggestion, and that is with regard to the supposed presence of ferrite, which I notice has been greatly emphasised by Mr. Hudson on a few of the micro-photographic illustrations exhibited on the screen.

In the first place it must be thoroughly understood that ferrite is considered to be a constituent of pure iron, and consequently free from carbon, etc., which I would suggest can only exist in a steel practically free from, or at any rate, very low in silicon, phosphorus, sulphur, manganese, etc. But on the other hand it is impossible to exist in cast-iron in such specimens as have been shown on the screen the latter part of this evening, owing, I consider, to the excessive presence of these elements, which would undoubtedly interfere with the atomic and molecular grouping of the eutectics which would be present in solid solutions. Under these conditions the presence of some of the eutectics would be masked by others. It is very interesting to notice that this supposed ferrite exists chiefly in the immediate neighbourhood of the separated graphite, which would induce one to think that this would really be ferrite, due to the rejection of carbon that has been thrown out of solution or combination on cooling the metal from an elevated temperature to a lower temperature while liquid. From what has been said, it appears quite evident that there is no free iron in cast pig iron, and that after the segregation of the graphite we still have left sufficient metalloids, etc., present to form eutectics throughout the whole mass, therefore I consider this so-called ferrite to be an eutectic of two or more elements, and it becomes, therefore, necessary to invent another name for it.

There is another very important question that I wish to mention, namely, it has generally been recognised that silicon is the chief element in cast-iron which governs the fracture of the pig, and which expels or throws the carbon, in the form of graphite, out of solution in molten cast-iron.

My past experience indicates that the chief elements governing the greyness or fracture, and also the separation of graphite, are chiefly sulphur

and manganese, and especially sulphur, That is to say, very small portions of these elements have a greater influence on the iron, as compared with that of silicon.

I freely admit that we have a great deal to learn yet from the examination of pig iron under the microscope, especially seeing that the subject is without doubt very much more complicated than the microscopic examination of steel, which has occupied the attention of iron and steel investigators for so many years past. The whole subject is still open for research, even from the very starting point. In other words the general principle upon which this microscopic research is founded needs examination.

Concluding, I consider Mr. Hudson's very interesting paper and research will be of great value to those interested in the use and manufacture of pig iron, and I congratulate him on the very able manner in which he has brought this subject before us.

Mr. RICKETTS (called on by the President): The only remark I have to make upon the excellent paper to which we have listened to-night, is with regard to the detection of sulphur under the microscope. Sulphur is present in cast-iron either as ferrous sulphide or as manganese sulphide, or as both. The detection of ferrous sulphide is difficult; it is brittle and powdery and is apt to fall out of the iron during the process of polishing; it thus leaves cavities filled with rouge, dust, etc., which cannot be readily identified amongst the graphite and dark pearlite. This sulphide has a low melting point, and is, therefore, one of the last of the constituents to solidify; consequently it does not occur in crystals of definite shapes, but takes its form from its surroundings. Manganese sulphide, on the other hand, has a very high melting point, higher probably than that of iron itself, and is one of the first constituents to crystallise; it, therefore, occurs in quite well-defined crystals, with sharp angles, and is of a dove-grey colour. It is, therefore, comparatively easy to detect under the microscope; in certain lights it somewhat resembles graphite in colour, but its shape is quite distinctive.

Mr. GEO. WILLIAMS (Ashton-under-Lyme), said that much of the information given in the papers had not hitherto been accessible to those engaged in the iron trade, and until comparatively recently it had not been possible to conduct such investigations on a practical scale. He congratulated the author on the paper.

On the proposition of the PRESIDENT, a vote of thanks was given to Mr. Hudson for his paper.

Mr. O. F. HUDSON (in replying to the vote of thanks): There have been one or two points raised in the discussion to which I should like to reply. Mr. Foster doubts the existence of ferrite in cast-iron, and

considers that this constituent occurs only in pure carbon steel. It was stated, however, in the paper (p. 121) that iron may contain a considerable amount of impurity, such as silicon and manganese, in the state of solid solution without apparently altering the characteristic appearance of the ferrite; it is generally understood that ferrite is "pure" iron only as regards its freedom from carbon. We are thus quite justified in saying that ferrite exists in cast-iron, as under the microscope it differs in no essential from the ferrite of steel. It was also mentioned in the paper that the name "silico-ferrite" was sometimes used for the ferrite of grey iron to distinguish it from the ferrite of steel which is nearly pure iron

Mr. Ricketts has referred to the presence of manganese sulphide in cast-iron. Manganese certainly exists to a considerable extent as manganese sulphide, and here, doubtless, is the explanation of the softening tendency of manganese, since manganese by combining with sulphur prevents that element exercising its injurious effect upon iron.

The Seventh Meeting of the Session was held at the Institute, Dudley, on Saturday, March 25th, 1905.

THE PRESIDENT (Mr. H. B. TOY) presided.

The minutes of the last Meeting were read, approved, and signed.

Messrs. D. G. Sutherland and Joseph West were elected members of the Institute.

Messrs. Richard Round and Jos. Raybould, the retiring Auditors, were unanimously re-elected.

The following paper was read by Mr. JAMES CALDERWOOD (Middlesbro') :—

SOME IDEAS; WISE AND OTHERWISE.

By JAMES CALDERWOOD.

A good many years ago Jules Verne's story, "Twenty Thousand Leagues under the Sea," was published. At that time the idea of travelling for that immense distance, or, indeed, for any distance, under water was rather fanciful; but who would now dare to say that the idea is absurd or the thing impossible? The impossibilities of yesterday are the commonplaces of to-day, and he is a foolish man who condemns any idea, however chimerical, on the simple ground that it has never been carried out before. A friend of mine in America, a metallurgist of some standing, always advocated the full discussion of all sorts of what he called "damn fool ideas," for the reason that something might come of some of them. To the metallurgists of fifty years ago Bessemer's idea of making steel without fuel was a "damn fool idea," but it revolutionised the making of steel, and gave civilisation an impetus it had never received before in the rapid spread of railroads. In the consideration of all sorts of wild and improbable ideas you may have to sift a lot of chaff; but if you get a few solid grains of good solid workable schemes you are paid for your labour.

I want in this rather hurriedly written paper to put before you a few ideas I have proposed, or heard proposed, at various times and in various places. I do not claim any originality, and I may not give you much information; but if I give you something to think about, something that may in any way help you in the problems you have to face daily in the Iron and Steel Works of Staffordshire, I think I may say I have not wasted your time or my own.

Some 12 years ago, when the Johnson Company, of Johnstown, Pennsylvania, determined to build a steelworks of their own, I was one of the men engaged on the design of what is now the Lorain Steel Works, at Lorain, Ohio. In Johnstown we had only the rolling mill for tram rails, and bought our steel blooms. We moved to Lorain, and built a Bessemer plant and blooming mill, in addition to the rail mill. One of the really hard problems of a rolling mill, and one which seldom receives the consideration it ought to, is the disposal of waste. All thought is given to handling the good product, and the waste, as a rule, is left to take care of itself, and as a result a considerable expense is entailed in getting rid of it. At the hot bloom shears in Lorain we solved this problem in a very satisfactory manner. On the delivery side of the shears we installed a swing

table, the idea of which you are no doubt all acquainted with; but in addition to its vertical swing, this table was also capable of receiving a horizontal motion, and could move out about 4 feet in a direct line from the shears. Underneath this table was the end of a conveyor, which ran out into the yard for 200 or 300 feet. The table was moved out or in by a hydraulic cylinder, so that it occupied one position or the other at the will of the shearman. Blooms for the rail mill ran out on the table, and were delivered by their own momentum on low cars: but for crop ends or short billets the table was in its outer position, and these pieces fell on to the conveyor below, which carried them out into the yard and dropped them alongside a sunken track, where they could be loaded as convenient. Little expense was attached to this method of handling, and 600 to 700 ons of steel per shift could pass through the mill with ease.

In drawing your attention to this contrivance, I do not for a moment suggest that any of you should rush off and propose to your various companies that you should instal forthwith movable swing tables and long conveyors. My idea is to impress on you that for economical working it is quite as important to consider how you are going to handle your waste, as it is to deal with the question of handling your good finished material. If your waste is, say 20 per cent., and it costs you as much to dispose of this as it does to handle the remaining 80 per cent, there is very serious leakage in your money chest. As you may have heard it expressed before, the primary and only object of all mills is not to make iron or steel, rails or billets, slabs or plates; it is to make MONEY. And every suggestion that helps us towards that consummation should be welcomed. I think you will find in a great many works the scrap question is sadly neglected, and a wonderful amount of money is mis-spent.

Of course, while we did some things in Lorain that were very well, we did others that were not quite so well. We made one somewhat disastrous experiment with the finishing mill. The Bessemer plant and blooming mill were new, but the rail mill was brought from the company's old place in Johnstown, Pa. The principal product was tram rails, or street car rails, as they are called in America. The mill is two-high, with three pairs of rolls, and in Johnstown was provided with the ordinary roller tables. Before the removal of the mill, a new set of tables, 6 in all, one on each side of each pair of rolls, was designed and ordered so as to be ready for the mill in its new location in Lorain. These tables were designed with the idea of doing away with all the high-priced labour at the rolls. Each table could travel from its own pair of rolls and take from or deliver a rail from the next pair. The tables were narrow, the rollers being only about 12in. long. Each table had at the end next the rolls a ring revolved by a motor, the purpose of this ring being to turn over the rail when required. The idea—on paper—was beautiful, though rather expensive. Almost everything was of cast steel, and each of the 6 tables had 3 motors, one for the rollers, one for travelling the tables across the rolls, and one for the turning ring. The whole arrangement was installed and the

mill started with it, but after a fair trial lasting for some weeks it was a flat failure, and the old tables had to be put back again. It was all very well as long as the bar being rolled kept reasonably straight, but, as you all very well know, we have not yet reached that ideal stage in rolling mill practice when we can confidently tell what shape and direction every bar will take when it leaves the rolls. And on that account the tables had to go, they were *too* ideal

In connection with this and some other things I may yet say, you may reasonably ask, why put before you schemes that were failures? Believe me, gentlemen, it is a good thing, a *very* good thing indeed, to learn how *not* to do things, especially if you can learn at someone else's expense. If our textbooks would sometimes tell us a little more of what to avoid, and insist a little less on what to do, they might prove better guides to useful knowledge. I have sometimes thought in the science of mechanical engineering we ought to have a decalogue, constructed on lines similar to that of Moses, in which only two commandments are positive, and the rest negative, "Thou shalt not." Perhaps the goddess of mechanics might speak and command thus:

I am the light of knowledge which led thee out of the land of empiricism and stage coaches into the land of steelworks and locomotives.

(1.) Thou shalt not prefer any art or science before me, as without me they are nothing.

(2.) Thou shalt not make a fetish of anything or anybody, but always look at things squarely for thyself.

(3.) Thou shalt not take mechanics in vain. It is a serious business.

(4.) Remember the first law of all mechanics, that you can get no more out than you put in, generally not so much.

(5.) Honour honesty and commonsense wherever you meet them.

(6.) Thou shalt not kill any idea you are too stupid to understand.

(7.) Thou shalt not put a machine to do work when a man can do it cheaper. Do not defame me by being mechanically wild.

(8.) Thou shalt not steal other men's ideas and pass them off as your own.

(9.) Thou shalt not be an expert witness.

(10.) Thou shalt not worry thyself over what other people are doing, decrying everything about your own place or country. If there is anything wrong, get a move on thee and better it.

The General Manager of Lorain Steel Company is an Engineer of exceptional ability and original ideas which he is not afraid to try in practice. After the steel works and mills were fairly off, the design of the blast furnaces was taken up, and I developed some of the General Manager's ideas, two examples of which I will give you. These particular two unfortunately came to grief, but I think there is something in them

worth your consideration The question of the style and size of metal mixer received very careful attention ; but after going through the various types and sizes at considerable length the General Manager burst on me one day with the idea of a *movable* mixer ; that is, a mixer on wheels. I say " burst on me " because " burst " is the only word that will express, as it were, the inspiration by which the idea was brought forth. The capacity of the mixer was to be 500 tons ; it was to be put on a carriage and to travel in front of the blast furnaces, which were to be provided with a very short pig-bed intended only for emergencies. In order to give us height for this mixer the hearth level of the furnaces required to be 18 to 20 feet above the yard level. I forget the details of the machine now, except that when loaded it weighed nearly 1,000 tons, and I had 48 wheels under the carriage to carry this immense load. The iron was to be run direct from the furnaces into the mixer on one side, and on the other side to be teemed into a ladle to be taken either to the steel works or to the pig-casting arrangement which I shall describe shortly. The main idea in the design of such a mixer was that it saved a handling of the molten iron, it avoided filling the ladles at the furnaces, conveying them to a mixer and back again. The wear and tear of ladles and linings and locomotives was to be saved, and when you are handling several hundred tons every day the saving in this direction would be considerable. Where we erred was, I think, in the size of the mixer. For my own part I still think the idea good and practicable, but I should limit the size of the mixer to 250 tons, when, I believe, a workable and economical machine could be made.

You will remember that this machine was thought of before the days of the tilting open hearth furnace, and long before the Talbot furnace, or the large holders half mixer, and half open hearth furnace were thought of. If it is workable and serviceable at all, I should say it is applicable to a blast furnace plant equipped with a pig casting machine, and with a Bessemer plant attached.

This brings me to the second somewhat revolutionary idea proposed during the time we were designing Lorain blast furnaces. You are all acquainted with the ordinary type of pig casting machine, a slow running bucket conveyor. at one end of which is a spout, into which the iron is poured from the ladle. The conveyor passes close under the spout, and each bucket is filled as it passes with molten metal. This is cooled and sets quickly, being discharged as pig iron at the far end of the conveyor. Instead of this, our general manager proposed to cast into iron moulds on cars. The ladles filled from the mixer were to be run to a central point, where we were to have a special design of casting spout, under which was to pass a train of low cars propelled by a special electric locomotive. The tops of the cars were made of easily removable iron moulds. While designing this machine I spent considerable time experimenting as to the proper size and shape of the moulds, and finding out how long it took the metal to set sufficiently by natural cooling to allow of its being dropped out of the mould. I had several moulds made of different sizes and shapes,

had them repeatedly filled with molten iron, and turned upside down to see how the pigs would leave the moulds. The intention was that the cars should, after filling, be run under an overhead yard crane, which would pick them up one by one, and discharge them where wanted. The cars were designed so that when loaded they were top-heavy, and when the craneman released them they would discharge themselves. As the pigs left them they turned right side up again, were lowered on to the track, and returned to be filled once more.

Unfortunately, before the time came for these two schemes to be carried out, I was in Russia, and did not see them tried. But I learned that they had to be given up, as they could not be made successful. I do not think much of the pig-casting car idea, but as I have already said, I think something could be made of the moveable mixer.

Casting steel ingots into moulds on cars was, I believe, tried in England many years ago, but for some reason or other was given up, and the casting pit adhered to with all its inconveniences.

The man who made a success of the casting car system was Mr. F. W. Wood, President of the Maryland Steel Company, whose works are located at Sparrow's Point, near Baltimore. Mr. Wood is a man of forceful character and of an ingenious turn of mind, not afraid to try new ideas. He started casting on cars when nobody else was doing it, and started a new Bessemer shop with it. It was a success from the first, and so far, at least, as America was concerned, was soon adopted nearly everywhere, and the casting pit, with its dangers and inconveniences, was abolished. In this country we are more conservative, and most Bessemer shops still hold to the casting pit. A more cogent reason, however, than conservatism, is often to be found in want of room. Most of our older Bessemer shops are jammed into rather tight corners, where expansion is almost impossible. But wherever it can be done at a reasonable cost, my opinion is that the system of casting on cars should be introduced, both in Bessemer and open hearth plants, as it is clean, economical, and safe.

Instead of the conventional hydraulic jib casting crane, Mr. Wood installed in the Bessemer shop of the Maryland Steel Company an overhead travelling crane, partly hydraulic, partly electric. The ladle is lifted directly by a hydraulic cylinder, which is placed on the carriage travelling on the crane girders, and the bridge and carriage derive their motion from electric motors. It was the first Bessemer installation of its kind, and it is the only one I have seen in a Bessemer shop, though such cranes are now common in Open Hearth plants. It works remarkably well, and handles about 800 tons of steel per shift with ease. The weakest point of the crane is the two sets of knucklejointed hydraulic pipes which are required for the lifting cylinder, one to allow for the bridge travel and one for the motion of the carriage. But even these give very little trouble, though I have no doubt that before long the hydraulic

cylinder will be dispensed with, and electric power substituted. After two years' experience with this crane, during which time I think I had something to do with almost every working part of it, I think it a safer and more convenient machine than the usual hydraulic centre crane.

Amongst many other noticeable features, I think the Maryland Steel Company's hot rail bank is very much worth anyone's consideration. Personally, I think it is the finest rail bank I have seen anywhere, and I have seen a few on both sides of the Atlantic. The ordinary engine or motor driven drum and wire rope arrangement is here not in evidence. There are 6 separate banks, each about 36 feet wide, contained in a building 260 feet long. The length of all banks is about 60 feet, and they are slightly inclined from the live rollers at the bottom end to the straightening machines at the upper. The live rollers run along the entire length of the whole 6 banks, and the whole arrangement is operated by two lads placed with their levers about the centre of the building. Between the rollers, to suit each bank, are swinging stops, which can be raised or depressed at will from the lad's pulpit, so as to deliver a rail to any bank as required. At the bottom of each bank is a hydraulically operated rack working into a pinion on a shaft which carries two sprocket wheels about 16 feet apart At the top end of the bank is another shaft carrying a corresponding pair of sprocket wheels, also a ratchet wheel and lever. From the end of this lever a rod runs down to the crosshead of the hydraulic cylinder. Between the two sets of sprockets run two chains with projections about 12in. apart, and each corresponding pair of projections engage a rail and take it forward as the chains are moved. As a rail comes on to the hot bank rollers, the lads, with the pull of a lever, put up a stop at the bank desired. The forward motion of the hydraulic pistan pushes the rail off the rollers on to the bank; the return stroke operates the sprockets, pushing the new rail about 12 inches up the bank, moving every rail on the bank the same distance forward, and (if the bank is full) delivering a rail to the straighteners. You will note that the whole bench of 50 or 60 rails is moved forward at every return stroke of the piston. On the face of it one would say it was a waste of power, but as compared with the usual skid arrangement, it is simply a question of moving the whole bank 2 and 3 rails at a time or moving all the rails slowly, at once. In both cases every rail has to travel the whole length of the bank of rails at once. My experience, at any rate, was that a less troublesome or more economical hot bank could not easily be found. The rails are properly cambered before delivery to the bank, and before they reach the top, they are practically straight.

A machine that is not very common in the iron and steel works of England is a fast running saw or disc for cutting iron or steel cold. There are several very good makes of the slow running saw, but when you have a great many pieces to cut, you have either to put several saws to work or to possess your soul in patience. The fast running saw does not make

nearly so clean a cut as the slow saw, but if you put power behind it, it will do the work very quickly. I have seen 80 or 90 pound flanges cut through in less than half a minute, but the driving power was nearly 200 horse. On the other hand, it would have taken the ordinary old saw about 15 minutes to make the cut. At one works I was connected with, we had once to saw a great many pieces of rail, several thousand, to a dead length. One slow cutting saw was going to take us the best part of a year to do the job, and was going to cost us a lot in wages. We designed and made a fast running saw for ourselves, a very simple affair. It enabled us to cut about 5 times as many per shift as we had been doing, besides reducing the cost per ton by 50 per cent, In fact it practically paid for itself on this one job alone, besides setting free the other saw for work that required to be more accurately done. For those who have much cold cutting to do, this class of machine is well worth looking into.

A neat little device that I have seen in some rail mills, and which may be new to some of you, is a machine for stamping the blow or cast number on the bars after they leave the hot saw. The machine consists simply of two brackets, each with upper and lower bearings. The lower bearings carry a spindle on which is a disc level with the live rollers. The upper bearings carry a spindle on which is a quadrant cut out to take the figures to be stamped. Between the two spindles is a coil spring of about ¼in. wire. As a rail approaches the attendant boy gives the quadrant a turn, and the momentum of the rail carries it on under the stamp. The quadrant swings round several times and stamps the rail an equal number of times. The figures are easily changed as new numbers are required, and a boy is the only attendant needed. Of course, in cases where the customer or the inspector insists, as they sometimes do, on having the bars stamped on the ends the machine is not applicable.

I had once to get up something to operate a butterfly blast valve located at some distance from the operator. We already had two such valves, operated by light wire ropes. The addition of a third pair of wire ropes was going to make things somewhat complicated, more especially as there was a corner to turn. It might easily, of course, have been done by hydraulic power, but we decided to do it electrically, so that we should only have to run a pair of wires from the working stage to the valve. We built two small electric magnets about 12in. long, and keyed a double-ended lever on to the valve spindle. One end of this lever engaged with a link connecting the yokes of the two magnets, and the other end was coupled to the rod of a small dash cylinder, the object of which was to prevent the action being too rapid. The arrangement worked admirably, the operator, by means of a small switch, being able to place the valve as he pleased. We certainly made the magnets strong enough. Before putting them in place I had them tried. At a distance of 1in. from the poles each magnet had a pull of 600 pounds. We erred on the large side, but we never had any complaints of the thing not working. Electro-magnets can be applied in many ways in iron and steel works, and are very

simple and efficient. The cost of power for them is trifling, and they require little or no attention.

One runs across sometimes some apparently simple things which, nevertheless, baffle explanation. In Sparrow's Point the Bessemer blowing engines are in the same house, and are supplied with steam from the same boilers as the blast furnace blowing engines. This is an excellent economical arrangement, as the steam is generated by the blast furnace gases. The blast pipe to the Bessemer plant is a 42in. steel pipe about 1,200 feet long. We required the old Bessemer engines for the blast furnaces, so we extended the building and put in two new engines for the Bessemer, connecting them to the old pipe. The old engines had to run about 26 revolutions per minute to give the necessary blast, having two air cylinders 84in. diameter; but the new engines had to run twice as fast, having one 84in. cylinder each. As soon as the new engines started the trouble began. It was not so very serious, but it was most unutterably annoying. The trouble was *noise*, and such a noise. A boilermaker's shop in full swing would have been a graveyard beside it. One would have thought that we had left at least a hundred rivetters and smiths inside the pipe, and that the whole gang were rivetting away for dear life. It was a horrible racket, and strange to say, sounded worse at the Bessemer end than the engine end, so bad, in fact that the negroes, coloured gentlemen I should say, began to think the pipe was bewitched, and would have been glad to stop work. The noise went on day and night without intermission while the Bessemer worked, and could be heard all over the town. I used to be in bed at night listening to it, and wondering how to stop it. Everybody from the president down to the labourers worried about it, and suggested remedies for it. We tightened and braced the pipe everywhere; we ran the engines singly and we ran them together; we altered the blast valves and re-altered them back again; we did this and we did that; but the abominable row went merrily on. The superintendent came out one day with a smile all over him, crying "Eureka!" He had discovered it! At the Bessemer end of the pipe there was a small receiver, intended to trap any moisture that might come along. This receiver had flat ends, and the superintendent maintained that it was acting like a drum, and that its vibrations were causing the racket. We took it out in double quick time, and carried the pipe straight through. But alas, alas, cures might come and cures might go, but the noise went on for ever. The removal of the receiver made no difference whatever. We solved it at last very simply, but I leave to my hearers the explanation. Someone suggested that a receiver at the engines was what was wanted. We did not build a receiver, but converted the section of pipe nearest the engine into one. About 30 feet from the second engine, we bolted a segmental cone into the 42in. pipe, reducing its size at this point to about 12 inches. The noise disappeared as if by magic, and, without any figure of speech, we were at rest.

In the rolling of steel there are many troubles of the least of which

is the cracking of ingots when being cogged. We can all, more or less talk learnedly, if somewhat hazily, of high sulphur or low manganese, of ingots too fresh or too hard, of bad steel or of burnt steel, and of many other troubles steel and the steelmaker are heir to. But one of the strangest cures for cracking ingots was tried as follows:—We had just started a new Bessemer plant in a works in Russia, and the mill manager had a fearful time with ingots cracking. Analysis showed that the steel was first class, but all the same it cracked badly, and the inspector was threatening to reject all rails. The usual recriminations went on between the mill and Bessemer managers. One said the steel was all bad, and the other said it was all burnt. All sorts of remedies were tried, physical and chemical. Ingots were made with hardly any taper, and ingots were made that looked like large wedges. But nothing seemed to do any good. The general manager gave birth to a brilliant idea. The steel was cast on cars, and he discovered that there was a joint in the crack near the casting point, and it was the jolt the molten steel got as it passed this point that caused the trouble. Two rails were rolled and cut 80 feet long, and laid right across the Bessemer shop, so that the steel might not be jolted. But the cracking of the steel and the cracking of the managers went on as before, and at the first mess in the shop these long rails took such fantastic shapes that they soon found a liquid gave in the converters. The trouble gradually cured itself, and I do not think anyone ever actually knew what was the matter. Verily, verily, to parody the words of Hamlet, there are more things in iron and steel than are yet dreamt of in our analyses.

I once had a funny experience with a rail mill engine. The mill was three high roughing and intermediate rolls and two high finishing, these last being short and having only the finishing pass in them. There was an engine on each end of the mill, the two being similar engines, only right and left hand to each other. Owing to the breaking of a piston we had smashed the cylinder of the finishing engine. We had a spare cylinder, but it belonged to the other engine. However, by rearranging the valve gear we made it work in, and finished the job at the week end. On Monday morning, after the mill had started, the mill mechanic, who was a first-class man, called me up on the telephone saying he would like me to come and see the engine. "What is the matter?" I asked; "won't she go?" "Oh, she goes all right," he said, "but she won't pull anything; she has stalled several times. I don't think this valve gear is all right." I went over to the mill and found the manager and Davy, the mechanic, dancing about the engine and advancing all sorts of theories about the re-arranged valve gear. It was taking the engine all her time to run the finishing rolls. If anything had gone wrong with the other engine she would have had to run the whole train, and evidently she could not do it. I spent quite a little time looking the thing all over, moving this and moving that, depressing the governor, raising the governor, but

all to no purpose; it made no difference, whatever I did. Davy swore it was the valve gear, and I swore it was not. Finally we went off to have a look at the drawing. Just as we were getting it out I said, "Are you sure all your valves are open on the steam line?" He paused for a moment, and a light seemed to dawn on him. "I wonder," he said, "if that butterfly is open." His language was a little more picturesque than I have expressed it, but you can imagine it for yourselves. In addition to the stop valve at each of the large engines we had a butterfly valve for use in emergencies. Back we went to the mill, and, sure enough, the engineman in starting up had forgotten to open the butterfly valve, and the engine was only running on the leakage. He pulled the lever over, and the engine went off as if she had got an electric shock. There was no more stalling after that, but we had a good laugh over it. Personally, I think all large mill engines should be provided with a strong butterfly valve, which need not be a nicely fitted affair. Every once in a while we hear of one of these engines running away and smashing itself, because the valve has stuck or broken. The butterfly valve will not stop the engine, but it can be shut in an instant, and it will at least bring the engine down to a reasonable speed and prevent damage. An ounce of prevention is worth a pound of cure any day.

In conclusion, I should like to say a word or two on the present craze for Americanisation. Frankly, I do not believe in it; that is, I do not believe in such Americanisation as numerous delegates and visitors to America have recommended. Some of these have rushed through several American plants, and have come back with a fearful tale of woe. England is being left behind! We must rebuild our mills! We must put machinery in place of men! Labour must be reduced or we are ruined! The ideas picked up by some of them are sometimes not only hazy but positively wrong. Why, a few months ago, in one of our leading mechanical papers, I saw the cambering machine (a machine indispensable in American rail mills) described, and, would you believe it, the writer cambered the rails the wrong way? I should have enjoyed seeing a straightener's face who got rails from that machine to straighten.

We have much to learn from America, and America has much to learn from us. They *do* learn a lot from England, but they are 'cute enough to get what they want and keep quiet about it. It is a great thing to be able to say nothing—at the right time. We can make as good steel here, and we can roll as good steel here as they can in America. We might with advantage copy a little of their hustle. It is wonderful what a lot of difference there is in your cost sheets between an output of 1,000 tons a week and an output of 2,000 tons. If your standing charges are 10s. per ton on the smaller make, they are only 5s. on the larger, and the cost of your steel is 5s. per ton less. And, furthermore, the item for coal, the item for repairs, and half-a-dozen other items will all be less. This is where the Americans score most heavily over us. *To keep your cost*

. . . . . This . . . .

with some amount of caution, or at least with a proper regard for what really constitutes economy. A little story which I should like to relate here will show you just exactly what I mean. A new manager was engaged at a works where only a day shift was being worked. The owners complained of their heavy cost, and the new manager proposed the establishment of a night shift in order to reduce the dead charges The manager believed the saving might be considerable, and said so. Permission for the change was given, and the night shift was duly installed. I believe when the new manager was installed the works were losing ten shillings per ton of rolled iron made. When the night shift was established the loss was reduced to just one half on double the output. So you see there is just that difficulty to watch. It is very well to aim at great outputs with a view often of keeping down or reducing the dead charges, but what has to be borne in mind is the nett result. In one part of his communication Mr. Calderwood mentions that he holds the view that we in England can produce steel of fully as good a quality in all respects as the American steelmasters can. I was glad of that pronouncement once more, from a gentleman, too, who has himself had an American ironmaking experience. I venture to endorse that sentiment very strongly, and I have done so before. In fact, I am prepared to declare that, given equal conditions, we are as far advanced in the manufacture of steel and iron in this country as they are either in America or Germany. And that is saying a great deal. Still, that is my deliberate conviction—given always, be it insisted—equal conditions with us as with either of them. In conclusion, I have been very much attracted by some facts of Mr. Calderwood's communication. We are all indebted to him for coming specially from the North of England to-night to set these thoughts before us in the lively way which he has adopted. He has given the Institute some very good notions here and there in his paper, and I am sure we can profit by his suggestions in the daily conduct of certain portions of our business.

MR. JNO. W. HALL: I agree with you, Mr. President, that many of us have been interested and perhaps amused by to-night's paper. It is rather different from the general run of papers we get. I have appreciated the paper from the point of novelty, and a number of matters are dealt with in works' management which would well repay consideration. Mr. Calderwood mentioned the casting of steel ingots into moulds on cars, and attributed the success of the system in America to Mr. F. W. Wood, President of the Maryland Steel Co., Baltimore, although he admits that the system had been previously tried in this country. It may not be exactly known to Mr. Calderwood that this system was originally attempted at the Landore Steel Works in South Wales, In some respects it was a success, but it was abandoned because the cars were carried on a circular turn-table, and the metal used to run over the table if anything went the least wrong with the operations. It is very interesting to notice that many steel works have

now returned to the casting of ingots in moulds on cars, but by mechanical methods free from the earlier objections. One defect which rendered the original casting on circular tables unsatisfactory and unmanageable was because the whole arrangement was constructed close against the furnace. Now the cars are taken outside when filled, where they are lifted off, and the front of the furnace is consequently kept clear. There is therefore no interference with the working of the furnace, and the casting process is much cooler and better for the men to handle. Mr. Calderwood speaks of the same American works installing an overhead travelling crane in the Bessemer shop instead of the usual lifting jib crane. In this country the same arrangement was first adopted, I think, at the Patent Shaft and Axletree Co.'s Works, Wednesbury, under Mr. Wailes The author advocates the employment of electro-magnets in iron and steel works, and states that they are simple and efficient. Personally, I should like to know much more concerning the electric magnets of 12in. long, which he states he once installed to operate a butterfly blast valve situated some distance from the engineer-in-charge. He states that at 1in. from the poles each magnet had a pull of 600lbs. Well, I wanted such a magnet as this some time ago, and I had a great difficulty in getting anyone to make it. Indeed, so great and numerous were the difficultics that we had at last to abandon the idea of an electric magnet altogether. The author refers to mill troubles arising from the cracking of steel ingots when being cogged, and he relates a troublesome experience in this connection that he had with a new Bessemer plant in Russia, the cause of which, he states, was never really discovered. I should like to ask him whether the cracked ingots were Bessemer basic ingots? [Mr. CALDERWOOD: They were not basic; they were ordinary Bessemer acid ingots] The author, after an American experience, warns us against what he terms the "present craze for Americanisation" in connection with the equipment and laying out of English works. I am glad he takes so sound a view. There has been a great deal of nonsense talked about this matter. I will illustrate what I mean. I remember in one instance hearing of a hot bed being put down by one establishment to save the labour of two boys. On paper the idea looked excellent and economical. But, mark the sequel—the hot bed necessitated the labour of four fitters to keep it in repair. That is a sample of the false craze for "Americanisation" to which I have referred. British iron and steel masters and British works managers and works engineers, civil and mechanical, have yet to realise that, attractive as American iron and steel practice may often appear, the conditions of work in this country and in the States are very often not alike. One essential difference exists in respect of profits In the United States iron and steel men can almost always be sure of their profit, and there is no anxiety on this score. Now, in England, what you have to do first is to look after your profits and see that they are there, and then have an eye to large outputs

after. A paternal Government helps the American manufacturers in this essential very considerably; in England we have no protective tariffs. The author, while conceding that there are with us even still, as in America and Germany, works that want improving, advises managers to make the best of their existing plant, and improve it only as they go along, and only with a thorough understanding of local conditions. With the wisdom underlying these remarks I am entirely at one. In America labour is much more expensive than with us, and therefore it is often much more preferable to supplant manual labour by machinery in America than it would be with us. That is only one reason out of many I might mention. Another reason for exercising judicious caution is that the Americans work to a much greater degree than we do in the direction of what is termed "specialisation" of output, We do not "specialise" in this country to anything like the extent that is common in the States, and it is useless for us to imagine that we can do so. And in this pronouncement I do not confine myself to steel rail manufacture; the remark applies equally to many other branches.

MR. WALTER JONES: I do not know anything, Mr. President, about iron or steel making itself, yet I have found plenty to interest me in Mr. Calderwood's paper. I was especially struck by the author's ten "Thou shalt nots." It is not everyone who will tell you the weak points which they have come across in their industrial and manufacturing experience. I remember writing a paper some years ago, and I tabulated causes of failure, quite a string of them. Someone who heard the paper queried the soundness of my judgment, and inquired why I had given prominence to failures as well as success. My reply was: I want to prevent a repetition of these things in others; and I believe I did a service to my fellows by chronicling what I did. One event of failure I recorded was very similar to the account given by Mr. Calderwood of his troublesome experience with a rail mill engine arising out of the neglect to open the butterfly valve, with the result that the engine was only running on the leakage, except that in my case we had water to deal with instead of air. The explanation of all our trouble we found at last was the simple circumstance that the S pipe was stopped up and not a spot of water would go through it. There are many points in the paper it would be well for us to ponder over, and the contribution as a whole has certainly been a marked departure from anything we have had at this Institute for some time. Mr. Hall, in his remarks on the paper, has referred to American specialisation. I quite concur in his criticisms on this matter. Unquestionably the American manufacturers have an important pull over us by reason of their practice of specialisation in their manufacturing operations. In the course of a recent visit to the States I found that with regard to nearly everything that is made in that country the producers lay themselves out either for one special article or a special series of articles The policy of the American manufacturers is that they first turn out their product or products in the

cheapest possible way by the thousands or the million, and then they proceed to find a market or markets. By this specialisation they are of course enabled to reduce their costs of production very considerably—to such an extent, indeed, that many manufacturers, I am persuaded, in this country have no adequate conception of. The author has prominently referred to the advisability, wherever possible, of increasing output, observing tersely, "To keep your cost down, there is nothing so essential as to keep your make up." But Mr. Hall has uttered some warnings under this head. Let me supplement his warnings. A few days ago I was speaking to a Scotch manufacturer, and I enquired how it was that the Scotch pipefounders could deliver pipes into Birmingham at the unheard of price of 11½d. per yard? I was anxious to know where the profit came in. The reply which I obtained was "that the delivered price did not cover the actual foundry cost." He offered some sort of explanation by remarking that he thought that large outputs and ability to sell at such prices as I have sketched "helped to keep down their common charges." For myself, however, I must confess that I could not see how goods sold at considerable loss could reduce the common charges, and I do not think this Institute will very readily see it either. How the Scotch pipefounders can reduce their common charges by such business as this passes my knowledge.

Mr. W. SIMONS: I have very much pleasure in complimenting the author for his paper, which is like himself, strikingly original. His remarks, although treated in a humorous way, are well worth reflection.

The cold saw referred to by the author is well worth consideration to all those engaged in iron and steel industries, and more especially the Staffordshire district, where a large amount of girder work is done and which requires cold sawing. There is no comparison in the cost of working with the old type cold saw which we now have in use, and the fast running steel disc saw referred to by the author.

Referring to the author's experience with rail mill engines. Although the incident may appear a little ludicrous, yet the point which the author wishes to put before us is a most important one, that is, the necessity of fitting such large type engines with a butterfly valve. I have known in my experience of two cases of separate large and quick running engines having raced away, owing to a mishap to the main regulating valve. In one case the damage caused was very severe, amounting to about £1,000. Had these engines been fitted with a butterfly valve, this enormous expense would have been saved. Although such a valve would probably not be absolutely steam tight, it would in any case prevent racing away of the engines

I quite agree with the author's remarks about the present craze for Americanisation. We are unquestionably behind in the adoption of the best and most suitable appliances, but there is still a greater evil in existence on this side of the water, and that is the necessity of keeping

the mills fed. Although this is getting a well worn subject, and has been pointed out in many papers and during many discussions, yet it still remains a fact. If we were to go through nine or ten mills in this district we would find the mills were not fed—either for want of steam, steel, or perhaps heating power—with a result that the cost of manufacture is very much greater than it should be. If the mills were kept going without all these unnecessary stoppages, it would be astonishing what reduction in cost could be effected, and before any considerable outlay is thought of we should see what is the utmost that can be obtained from the existing plants

Mr. WALTER MACFARLANE: Like the previous speakers, I have profited by this evening's paper, if only through its originality. Wisdom as well as humour runs through the communication, and I congratulate the author upon his departure from the usual lines. I am also pleased to see Mr. Calderwood again in Staffordshire, if only for an evening. There are numerous topics in the paper to which attention might very well and very profitably be devoted. Mr. Calderwood tells us an experience of the Lorain Steel Company in early days with blast furnace mixers. Notwithstanding the non-success as recorded of that company with a moveable mixer of 500 ton capacity, Mr. Calderwood adheres to the idea that there is something "good and practicable" in the device of a moveable mixer. I see, however, that he limits the capacity of a workable machine to 250 tons, or just half the size of the big one that broke down at the Lorain works. I submit, however, that Mr. Calderwood's views on this practice are fundamentally wrong. Wherever practicable, the mixer should be stationery and the fluid metal brought to it When, two or three years ago, I set before the members of this Institute a rapid sketch of modern steel manufacture, I suggested, perhaps it may be remembered, that in blast furnace work in many instances, all the turmoil and delay and expense involved in the employment of ladles might be avoided by heightening the position of new blast furnaces and causing the metal to flow down spouts into the mixer. At the Lorain Works the same idea was attempted to be carried out, but in an opposite manner—the ladle track was brought lower. I pass now to the subject of Americanisation, or rather the "craze" for it. My views upon this question are already sufficiently well known to this Institute. I have frequently expressed them. But upon one point I should like to make an observation Mr. Calderwood goes the length of saying that "We might with advantage copy a little of America's hustle." Upon this my comment is, that if it is only to be "a little," that is all right, and I have no objection to offer. But if it is to be such an amount of hustle as leads to the cemetery at 40, I hope we shall be kept far from United States practice. Solomon's text might be set in jewels: "I saw therefore that there is nothing better than that a man should rejoice in his works." I think it would be well if we could keep at that point where the man in the works should have that degree of steady

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The President concluded by proposing a vote of thanks to the author.

Mr. L. D. THOMAS seconded the vote of thanks to Mr. Calderwood, and remarked: Mr. Calderwood has provided us with a very serviceable paper to think about. Mr. Calderwood's conclusion after his Transatlantic practical experience, that American iron and steel practice, taken all round, is not superior to that to be found in our own country, was very gratifying. Mr. Macfarlane especially, I believe, would be very proud to hear the pronouncement. I am of much the same opinion as Mr. Calderwood And I go further. I hold that neither Germany nor Belgium nor any country in the world can surpass our best work and practice. There is one thing I often think the Americans forget in their boasting. It is that it is at bottom British brains and men which have taught them and made them what they are. Commandment VI. of Mr. Calderwood's industrial decalogue reads thus, and it is a good one—"Thou shalt not kill any idea you are too stupid to understand." Now just there is the secret of much of the progress which the United States has, we all admit, made. Years ago, when Transatlantic iron and steel manufacture was in its infancy, if any young man connected with an iron or steel establishment in this country ventured to suggest to his employers, or to the management, any alteration or improvement in the manner or principles of production, in nine cases out of ten the would-be improver was immediately met with the remark—"What do you know about it?" and was treated accordingly. That was killing an idea; that was a breach of the sixth commandment. Well, what was the result? You all know. Immediately the young man referred to transferred himself and his ideas to the United States or to some other part of the world where he would be listened to—where he could obtain a hearing and his improvements get a trial, and a fair trial. And, as we all know, and now regretfully acknowledge, dearly has this country suffered for her conservatism. English brains and ideas were transferred to the other side of the Atlantic, because inventors could not get their inventions taken up in England, and granted the means and and chances of experiment which were denied to them at home these English and Scotchmen have, in absolutely numberlessly instances, proved that their ideas and discoveries had grit in them, and were notable. The advantage to America, Belgium, Germany, and other countries to which they have migrated has been enormous. In iron and steel manufacture, and in many other metalliferous and engineering industries, the countries I have named are now either almost or altogether on a level with ourselves. This is admitted, though I am glad to say we are not surpassed by any. All this has come upon us for our breach of the principles taught in Mr. Calderwood's sixth commandment. We heard to-night for the hundredth time, and to-night from one who has had practical experience of what he writes, that the American aim in iron and steel manufacture is first to get a large output. But, what

about finish? I much question if in this respect American and German products, taken all round, are equal to ours. And the same remark applies to many hardwares and metalliferous goods generally. If it is not so, why do we hear of foreigners stamping the name "Sheffield" and other British marks upon goods not made in England? With evidence such as this before us, there is no occasion for English manufacturers to be down or get disheartened because of foreign competition, or to imagine that they are beaten. There is ability and energy in British manufacturers yet, and I believe we shall yet declare it to the world. We have lost something—perhaps much—in the past, it is true, by our supineness and what I may term industrial conceit, but I believe these conceits and indifferences in the face of international competition are fast passing away. Mr. Calderwood has spoken concerning what he terms "Americanisation" I am glad that he has declared in favour of a gradual reconstruction and the reorganisation of our works rather than in favour of wholesale and rapid transformation. I am certain this is the safer plan, and that in the end it will be found most effective. Improvement little by little should be the motto of our works managers—"make haste slowly." In conclusion, I am persuaded, as I have already suggested, that even if our mills cannot turn out as large a tonnage as in America in a given time, we can, and do on an average, turn out a better article, and, in the long run, it is quality that pays.

The vote was passed, and the meeting concluded.

THE ANNUAL MEETING.

The Annual Meeting was held at the Station Hotel, Dudley, on Saturday, April 29th, 1905.

Mr. WALTER JONES (Vice-President) presided.

The minutes of the last Ordinary Meeting were read, adopted, and signed.

Mr. J. R. Meiklejohn was elected a member of the Institute.

THE SECRETARY (Mr. W. H. CARDER), read the Annual Report, which was as follows :—

REPORT OF COUNCIL FOR SESSION 1904-1905.

The Council congratulate the members on another successful Session.

The usual Summer Excursion took place on the 29th June last, when between 80 and 90 members visited the Works of The British Westinghouse Company, Trafford Park, Manchester, and were shown over the whole of that very extensive establishment. After inspecting the Works the party returned to Manchester and dined at the Grand Hotel, the President having as guests several of the chief officials of the Westinghouse Company, to whom he expressed the thanks of the members for the courtesies shown them during the day.

Carrying out the ideas suggested by the President at the last Annual Meeting, an Excursion to Glasgow and the West of Scotland was arranged in August last. On the 18th of that month a party of 26 journeyed to Glasgow, where they were met on arrival by several of the members of The Scottish Bar Iron Association and members of the Council of the West of Scotland Iron and Steel Institute, and were entertained to tea at the Central Station Hotel, after which arrangements were made for visiting different works on the following day.

On the 19th the members visited the following works in the Coatbridge District :—The Victoria Iron and Steel Co., Limited ; The Wilson and Union Tube Works, The Rochsolloch Works of the Waverley Iron and Steel Co., Limited ; The Waverley Works, The Clifton Works of Messrs. Wylie and Co., Limited ; Messrs. J. Spencer and Co.'s, Phœnix Iron Works ; and the Coats Iron and Steel Works of Messrs. Paterson, Downs, and Jardine At 6-45 p.m. the members were entertained to dinner by the Scottish Bar Iron Association in the Central Station Hotel. Mr. A. Colville (Chairman of the Association) presided, and many members of the Bar Iron Association and of the West of Scotland Iron and Steel Institute attended.

After dinner, the party adjourned to one of the rooms of the hotel. Mr. Colville, in his remarks after welcoming the members of the Institute to Scotland, expressed his hope and that of Scotch ironmasters generally, that the ironmasters in Staffordshire would consider the advisability of meeting the ironmasters of Scotland and the North of England in conference with a view to avoiding home competition.

Mr. CLARK (Steel Company of Scotland), Mr. D. GARRATT, and other speakers explained how the Scottish Bar Iron Association had benefitted the members of the local trades in regulating output and prices, and emphasized Mr. Colville's invitation for a conference to extend the principles already in operation.

On Saturday, the 20th, part of the members (who were unable to remain until the following week) visited the Clydesdale Works of Messrs. Stewart's and Lloyd's, Limited, the other members of the party going on a sea trip to the Isle of Arran, returning to Rothesay on the Saturday night, where they stayed until Monday morning, travelling to Glasgow on that day and visiting the Clydesdale Works and Messrs. D. Colville and Son's Works at Motherwell.

Tuesday, the 23rd, was spent in visiting the Works of the Glengarnock Iron and Steel Company, Glengarnock.

On Wednesday morning, the 24th, a visit was paid to the Blochairn Works of The Steel Company of Scotland, the party returning from Glasgow on the Wednesday afternoon.

During the whole of the visit the members received every kindness and attention. Whatever information was asked for was readily given, and there was abundant evidence of the earnest desire of our Scottish friends to make the visit as instructive and as enjoyable as possible. At the first Council meeting held after the visit, resolutions were passed thanking the members of The Scottish Bar Iron Association, the West of Scotland Iron and Steel Institute, and others who had contributed so much to the success of the visit.

On the 17th September a party of between 90 and 100 members visited the new buildings of the Birmingham University at Bournbrook, where they were received by Professor Turner and members of the staff and conducted over the buildings in course of construction, and also through the Engineering and Metallurgical Departments—the latter was in operation.

On Friday, the 28th October, a small party visited Messrs. Tangye's Works at Soho, where they were shown through the various shops and hospitably entertained. Before leaving, the President conveyed the thanks of the members to Messrs. Tangye for allowing the members to visit their works.

Seven Ordinary Meetings have been held during the year, at which the following papers have been read :—

15th October, 1904.—Address by the President.

29th October, 1904.—Paper illustrated by practical experiments on the Electric Smelting of Iron and Steel, by Mr. J. H. Stansbie, B.Sc This meeting was held in the Lecture Room, Metallurgical Department, of the Municipal Technical School, Birmingham.

26th November, 1904.—Paper by Mr. J. H. Hamilton, B.Sc., on The Gas Engine in Iron and Steel Works.

17th December, 1904.—Paper on The Garrett Re-heating Furnace, by Mr. J. S. Trinham.

21st January, 1905.—Paper on The Stirling Boiler, by Mr. C. E. Tarbolton.

18th February, 1905.—Paper on The Microstructure of Cast-iron, by Mr. O. F. Hudson.

25th March, 1905.—Paper on Some Ideas; Wise and Otherwise, by Mr. J. Calderwood.

All the meetings have been well attended. The Council earnestly hope that members will endeavour to provide a good selection of papers for the coming Session

During the year 35 members (4 Honorary and 31 Ordinary) have joined; 2 members have died, namely, Mr. C Bagnall and Mr. H. Le Neve Foster; 6 have resigned, and 8 have left. The state of membership is as follows :—

Honorary Members	...	53
Ordinary Members	...	224
		277
In April last the total number was		258
An increase during the year of		19

The finances continue in good condition. In May last the Trustees completed the purchase of £100 worth of Birmingham Corporation Stock at £79. The balance of the year's transactions is £7 2s. 6d., and as is shown from the audited balance sheet herewith, there was on the 31st December last a balance of £129 2s. 5d. after discharging all liabilities up to that date.

For the Excursion during the coming Summer, the Council suggest that a visit to either Middlesbrough or Brymbo, or some of the Manchester Engineering Works, will prove both interesting and instructive.

For the Council,

WALTER JONES, Vice-President.
WILLIAM H. CARDER, Secretary.

THE TREASURER (Mr. JAMES PIPER) read the Balance Sheet.—(See page 162.)

THE CHAIRMAN, who said that they might heartily congratulate themselves upon the society's position, proposed that the report and balance sheet be received and adopted, and printed in the Institute's *Proceedings*.

Mr. Jos. BROWN seconded, and the resolution was carried.

Mr. H. SILVESTER, in a complimentary speech, proposed the election of Mr. Walter Jones as President for the ensuing year. He observed that the Institute continued to increase in numbers, influence, and funds.

Mr H. PILKINGTON seconded the proposal, remarking that he thought Mr. Walter Jones would carry on the business of that Institute with the same assiduity with which he carried on his own business and with the same success; the resolution was carried unanimously.

THE PRESIDENT suitably replied, and proposed a vote of thanks to the retiring President, Mr. H. B. Toy, for his services during the past year. He was sorry Mr. Toy was not with them that day, owing to his absence abroad.

Mr. JAMES PIPER seconded, and the vote of thanks was carried.

THE PRESIDENT then proposed that Mr. William Somers (who, he remarked, was a son of Mr. Walter Somers, one of their past-presidents) be elected vice-President for the ensuing year. They all knew Mr. Walter Somers as a very hard worker and as an enthusiast in many good causes, and he thought his sons (including this one) were following pretty much in their father's footsteps.

Mr. SILVESTER seconded, the resolution was carried, and Mr. WILLIAM SOMERS expressed his thanks.

On the proposition of Mr. W. B. RUBERY, Mr. James Piper was re-elected treasurer, and Mr. William H. Carder was re-elected secretary.

THE SECRETARY said the next business would be the election of the Council, which should consist, according to the rules, of 21 elected

members, and 4 ex-officio members. He then read the present list, which showed two vacancies

Mr. YEOMANS proposed, and it was seconded, that Mr. H. B. Toy and Mr. W. H. B. Hatton be elected to fill the vacancies, and that the Council for the following year consist of Messrs. Thomas Ashton, John Bate, William Brooks, Joseph Brown, Robert Buchanan, Alfred Cookson, James Donechay, Richard Edwards, David Evans, Wm. J. Foster, Jno W. Hall, W. H. B. Hatton, Richard Lythgoe, Frank East Nurse, Herbert Pilkington, W. B. Rubery, H. Silvester, Walter Somers, Leyshon D. Thomas, H. B. Toy, and Thomas Turner.

Mr. JAMES PIPER said that in the absence of Mr. Toy, he proposed, as a matter of form and on that gentleman's behalf, a resolution to the effect that the next annual meeting of the Institute be held in Birmingham instead of in Dudley. Mr. Toy thought that the meeting would be better attended. He (Mr. Piper) simply moved it as a matter of form, and would leave it with the meeting. He could not say that he had much sympathy himself with the proposed change.

Mr, H. SILVESTER said he would second the proposition, though he was perfectly willing to go with the majority, whichever place they selected.

Mr. H. PILKINGTON proposed as an amendment that the annual meeting should be held in Dudley. The Institute had grown up in that old historical South Staffordshire district of which Dudley was the centre. He was afraid the proposal was only the thin end of the wedge towards taking the whole of the Institute to Birmingham. And then the next thing would be to take it to the University. He objected to the Institute becoming the satellite of any academic institution.

Mr. RUBERY seconded the amendment.

THE PRESIDENT said the Institute had grown up in that locality, and it would, he thought, be better for it to remain there.

Mr. PIPER remarked that the meetings used to be held in turn at Walsall and Wednesbury, and Mr. WALTER SOMERS observed that the society was originally started at Wolverhampton.

The amendment was then put to the meeting and carried.

On the resolution being put to the vote it found no supporters. The amendment was then put as a substantive motion, and was carried unanimously.

The question of the place of excursion was next discussed, Manchester, Brymbo, and Sheepbridge, being suggested.

It was also resolved that about the middle of July would be a suitable time, and that the Council be authorised to make the necessary arrangements.

Mr. G. K. CHAMBERS suggested another day than Saturday for the ordinary meeting of the Institute. Had that matter been brought forward at any previous annual meeting?

THE PRESIDENT: Not recently. Not perhaps within the last five years.

Mr. CHAMBERS: I should like to propose that the meetings should be held on some other day than Saturday.

THE PRESIDENT: Personally I am surprised that the question has not been raised time after time. It is a most inconvenient day. I like to rest on Saturday evenings after working all the week.

The proposition was seconded.

Mr. PILKINGTON explained that the idea of altering the day was not new. They tried the experiment once, and it was not at that time successful. It seemed to be a point which could only be settled by ascertaining what would be best for the convenience of the members generally.

Mr. SILVESTER said it had always been found that on Saturdays they got the best attendances.

After some further discussion the resolution was put and lost.

The members and friends afterwards dined together.

The chair was occupied by the PRESIDENT.

Letters of apology were received from the past-president (Mr. H. B. Toy), who was in Germany; Mr. Tom Westgarth, of Middlesborough; Alderman Job Garrett, Sir Alfred Hickman, Mr. Stanley Baldwin, Mr. Thomas Ashton, Mr. Joseph Colley, and others.

The toast of "The King, Queen, and Royal Family" was proposed by the PRESIDENT.

PROFESSOR THOMAS TURNER submitted "The Iron, Steel and Coal Trades." He said: I am very much obliged to you, sir, for the opportunity of once again proposing this toast. I believe that during the twenty years or so that I have been connected with this Institute I have had more than once, the pleasure of proposing this toast, and, as you will quite understand, it is not easy on an occasion of this kind, speaking in the same room, to many of the same people, on a similar occasion, to say anything that is new. I may, therefore, perhaps, repeat what I have said on a previous occasion. We are justified to-night in referring to the immense improvement which has been made in modern times in the industries with which we are ourselves connected—the iron, steel, and coal trades. I suppose that everyone who is deeply interested with any subject or branch of

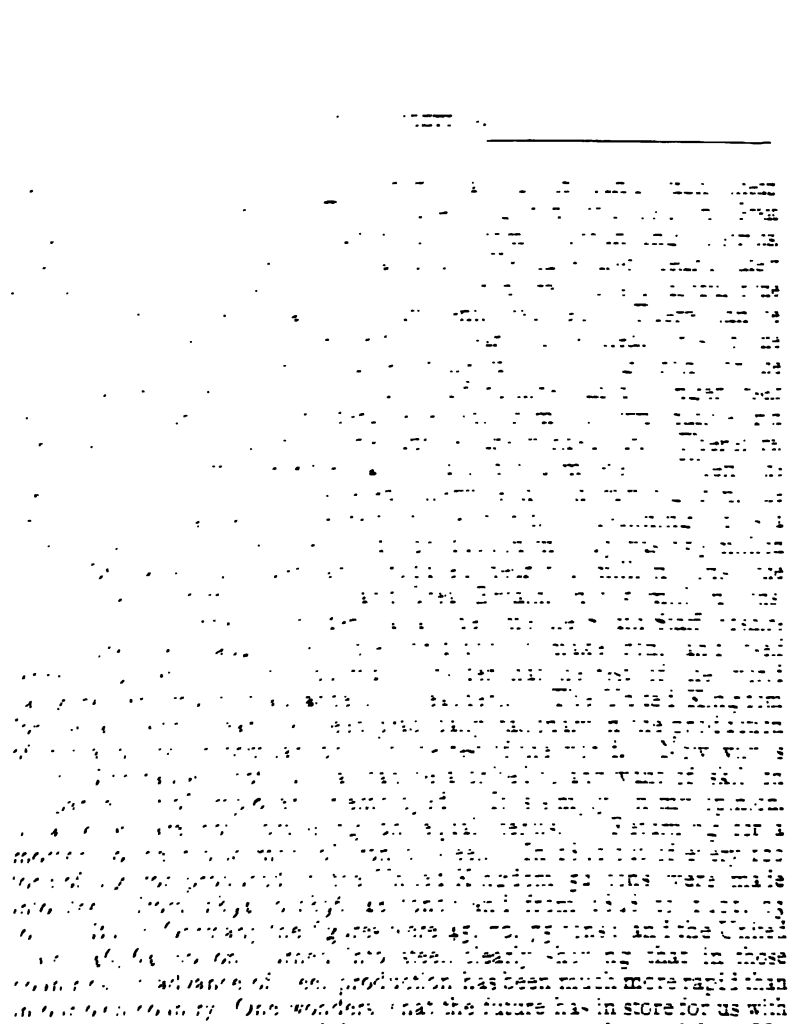
work, gets in time to think that his subject is the most important in the world. I remember some time ago speaking to the instructor in boot and shoe manufacture for the county of Stafford, and he was telling me the most important subject taught was boot and shoe making, because a difference of one-twentieth of an inch in the measurement made all the difference between comfort and discomfort. But a day or two afterwards the Directress of the Cookery School told me that cooking was certainly the most important of all subjects, because (she argued) apart from good cooking, you could not have strong workmen nor happy homes. We naturally divide men, in our estimation of them, according to the relative importance we attach to our own work, and to the work in which they are engaged. As a student in mathematics I was told mankind could be divided into two classes—those who used the calculus and those who did not. I was afterwards reminded by an eminent authority, who was once President of the Chemical Society, that there are other ways of classifying mankind. You can classify mankind, in this country at all events, into those who pay income tax and wish they didn't; and those who dont pay income tax and wish they did. That is not altogether, however, a complete classification, because I find that there are a certain number of men who keep quiet and ought to pay income tax but dont. But to come back to our subject. We may divide mankind into two classes—those who are interested in the iron and coal trades and do not know it, and those who are so interested and do know it. For all mankind are interested in the iron trade, either directly or indirectly. Because apart from the iron trade, we should (to revert to our former instances) have had no boots, since upon the use of our iron and steel tools depends the industry of shoemaking. Nor should we have had any cooking, or anything to cook, for the manufacture of cooking utensils, and indeed, in many ways our daily bread, depends upon iron. I might even go further and say, apart from the iron trade, we should even have had no income tax, because we should have had no income whatever upon which any tax could be levied. Then again, the difficulties of civilised countries at the present time are likely to be connected with the population question. The birth-rate in several countries, including our own, is steadily decreasing; but I think you will find that for productiveness in this respect, the iron working and colliery districts have been pretty well at the head of other classes of the communtty in this country, and therefore have contributed to the country's general progress and prosperity. We may also claim for the iron and coal trades that, barring the accidents which unfortunately do afflict a considerable portion of the workmen, those trades are healthy and reasonably remunerative.

On looking through the world, we find that wherever we have the iron and coal trades well developed, we also have all the modern sciences and arts. Take the three chief countries, the United States, Germany, and Britain. We find that these three countries between them practically

monopolise the coal trades and metal trades of the world. In the coal trade we lead in production, producing nearly one-third of that of the whole of the world; the United States, one-third; Germany, one-sixth; and the whole of the rest of the world, one-sixth. Taking the production of pig iron we find that Britain produces one-fifth; the United States, two-fifths; Germany, one-fifth; and the rest of the world, one-fifth. These figures would have been different by 10 or 20 years ago, because we should not be leading all the world in iron and coal. At the present time, as an Empire we lead in gold only. We produce half of the world's gold, the United States produces one-quarter, and the other quarter is produced in small quantities all over the globe. In silver we produce as an Empire one-sixteenth; the United States, five-sixteenths; Mexico, seven-sixteenths; and all the rest of the world, three-sixteenths. Of copper, of which metal we were fifty years ago the leading producer, we now produce so little in the form of native ores that you cannot express it in a convenient fraction, but Europe produces one-sixth; the United States, one-half; Mexico, one-twelfth; and the rest of the world, one-quarter. The output of lead is—Europe, one-third; the United States, one-third; Mexico, one-ninth; and the rest of the world two-ninths. As to zinc, the proportions are—Britain, one-eighth; the United States, a quarter; rest of Europe, five-eighths; and there is none anywhere else. So I think you will see in looking through these figures, though they are of course only approximate, that they will yet assure you that scientific progress, the comfort of the people, the advancement of the nation, or in short all those things which we associate with modern civilisation, are also associated with the iron and steel and coal trades, and more or less also with the other metals for the production of which iron and steel and coal are necessary. To-night we are interested more in the metallurgical and mining industries of our own particular district, and it has been a pleasure to me, in the last few months, to have an opportunity of visiting some of the leading works of the district. I must acknowledge the kindness with which I have been treated, and I have been struck with the way in which one meets old friends in the works in altogether unexpected quarters. One man the other day, whom I first did not recognise, said when I enquired if we had met before, that I ought to know him as I had taught him all the metallurgy he had ever learnt. The people one knew as youths, grow gradually into men, and you find them occupying more and more important positions as time goes on, and it is a pleasure to know that this is so. I have been pleased to see how, during the last year or two, important improvements have been introduced into the various Staffordshire works. Large sums of money have been sunk, and I feel we have, in some directions at all events, even better chances of holding our own than a few years ago. We used to say, in connection with the iron trade of the district, that the old dog died hard, or words to that effect; but though the iron trade now may not be as vigorous as some might hope,

still the trade of this district is, I think, we may say at least, as satisfactory as other districts in the country, and employment is uniform; and on the whole, although I never knew a man who would not like a little more money coming in, yet I say that upon the whole we can congratulate the country upon the amount of work in hand. Well, I must not encroach any more upon the time of the Institute, but I have said quite enough to assure you—if it really had been necessary to assure you—of the importance of the iron and steel and coal trades both to the world, to its several countries, and to the district in which we ourselves dwell. Gentlemen, I give you "The Iron, Steel, and Coal Trades," and I couple it with the names of Mr. Pilkington and Mr. Hughes.

Mr. H. PILKINGTON, M.Inst. C.E.: In response to this toast, so ably proposed by Professor Turner, I have to inform you that I am one of those poor people engaged in the iron trade, and I know it. Unfortunately, people engaged in the iron trade are not able to put their hands upon that gold which Professor Turner says is being produced. Formerly this toast used to be confined to the district, the toast then being "The Staffordshire Iron and Steel and Coal Trades," but now I see it has a wider scope. I came across some old figures the other day which were extremely interesting to me, relating as they do to this immediate neighbourhood. These showed that some years ago there were within a small radius of this room 153 blast furnaces, 2,155 puddling furnaces, and 342 mills rolling iron. When such figures are contrasted with to-day I think you will say that a great deal of the gold has left this district at all events, and I don't know that the general position in the United Kingdom is very much better than that in South Staffordshire. There was a time when South Staffordshire produced not only one-third of the pig iron, but practically one-third also of the finished iron of the United Kingdom. At one time this country as a whole produced 3 million tons of finished iron per annum. We don't now produce one million. That must be attributed to a very great extent to the advent of steel. But when one compares the relative positions of our own and other countries engaged in this trade, one cannot help but feel that we do not hold our own as regards both iron and steel production. Last year the whole world produced 47 million tons of pig iron, and the United Kingdom produced what we have produced annually for twenty years, namely, about 8 millions. Certain figures which were brought out in 1854 showed 6 million tons of pig iron produced in the world, and the output of the United Kingdom was just one-half of that. It seems to me that in this country we are undoubtedly losing ground in regard to iron and steel production. I don't think, notwithstanding all that has been said about our American friends, that on their merits they could, without tariffs, produce iron and steel any cheaper that we can. Notwithstanding all we have heard about the dying iron trade of South Staffordshire, we must never forget



advance of iron production has been much more rapid than [illegible]. One wonders what the future has in store for us with regard to the consumption of these enormous masses of material. Mr. Turner spoke about the production of iron and steel per head of population. I have always preferred to regard the relative state of peoples from the standpoint of their consumption of iron per head. The latest figures which I have, namely, those for 1913, give the annual consumption of iron and steel per head of the inhabitants as follows: The United States, 499lbs.; Great Britain, 470lbs.; Belgium, 421lbs.; Germany, 368lbs.; Sweden, 268lbs.; France, 165lbs.; Canada, 109lbs.; Austria-Hungary, 69lbs.; Spain, 41lbs.; Russia, 39lbs. But when you come down to Italy, 28lbs. per head, and Japan 11b., you can see that there is an enormous field for consumption; and the whole of Africa, Asia, and Australia are all classified in figures of less than 1lb. per head. That only shows that it is to our colonies and dependencies that we

must look for an outlet for our production. I dont think that in this Institute we dare mention such a thing as the Tariff Reform question, although I remember that a distinguished local member of Parliament some time ago gave you a paper on that subject; but I will just venture to inform you that a prominent man, when speaking in Sheffield lately, referred everyone to the Scriptures, recommending them to the 41st chapter of the Book of Genesis, and the 35th verse—"And when all the land of Egypt was famished, the people cried to Pharaoh for bread, and Pharaoh said unto all the Egyptians, 'Go unto Joseph; what he saith to you, do.'"

ALDERMAN JOHN HUGHES also responded. He said: My task is a very light one this evening, namely, to respond on behalf of the coal trade. The case as to coal can be put into a nutshell. We have large supplies but we want a greater consumption. Our profits are very small and our output at the collieries is diminishing. Unless something is done to use more of the coal that is produced in this district, we shall all be starved to death. Since our last meeting a report has been been issued by the Royal Commission on Coal Supplies, who tell us that they have made a calculation to the effect that there are nearly one hundred thousand million tons of coal in the United Kingdom down to a depth of 4,000 feet, including a one-foot seam. But you all know it is impossible to work a one-foot seam at such a depth. At the present time the deepest pit in this country is something like 3,000 feet, and the deepest in this neighbourhood is perhaps 2,500 feet. We are opening two districts, one at West Bromwich and one at Baggeridge, and we are putting down at these two collieries what I may fairly say are two of the best plants in the world, capable of raising 5,000 tons of coal per day, to supply the iron works and furnaces of this neighbourhood; but unless we go to Joseph or some other market, or some other place, I am afraid it will be no good raising the coal. Some of the collieries have been working only two or three days a week for some time past. To have to play two-thirds of the time is a state of things that ought not to exist. Employment is also short in the iron trade. In my young days men used to go on Monday night to fettle the furnaces and then go on through the week steadily, and then the men were doing well; but how can they be doing well at the present time when they have to play through shortness of work, and when there are two men for every one man's job? You may put your best machinery down, and have your best managers, but if you have not got the trade you cannot do anything. What the country wants is more employment. You should urge upon authorities the need of taking steps to see what is best to be done. I thank you very much for coupling my name with the toast.

THE MAYOR OF DUDLEY (Mr. G F. Thompson) proposed the toast of "The Institute." He said: As Mayor of the town I offer you a

hearty welcome. I see from your report that you have had a good and interesting session. I also notice that your members are more than last year. An important matter for a district like this is the saving of labour. I remember that four or five years ago I went over a South Staffordshire ironworks with a large Colonial merchant, and afterwards he said: "How is it you use so much manual labour, especially in wheeling materials about, which, I should think, should be done by some mechanical means." Well now, the same idea seemed to strike me. But this remark does not apply to such works as Earl Dudley's where a great deal of the production is turned out mechanically from start to finish.

THE PRESIDENT: I have to respond to this toast for the Institute. The Institute has been in existence for a good many years, it appears to have done very well without my assistance and to have had some very excellent officers. Mr. Toy has rendered good service as President for the past year, and Mr. Walter Somers rendered very excellent service for three years in succession. I only hope the Institute will go on successfully and continue to prosper. The only policy I have to suggest is—whatever you have to do, do it with all your might, and I think if we only keep that idea before us (as other presidents have done) there is no reason why as an Institute we should be less successful than in previous years. I simply ask you to do your duty. So far as I am concerned I will try to do mine. I shall follow as far as possible in the footsteps of previous presidents and try to do what I can to increase the membership and to make the meetings interesting and attractive. I have been much impressed with the unanimity and fraternal feeling of our Council meetings and other gatherings, and the attendances are such as I think would reflect credit upon any society of this kind in the world. Your Council meetings are attended regularly and punctually and all alike seem willing to do their share.

I beg to thank the Mayor of Dudley for his attendance, and I can endorse what he has said with regard to the fact that some of the works are woefully behind in introducing labour-saving appliances. People do not seem to take them up, so that sometimes it really costs more to sell a new appliance than to make it. If all the manufacturers were to adopt labour-saving appliances profits would be bettered and trade would stand a better chance. With regard to coal, I am pleased to hear we need have no fear as to the falling off of the supply. A few years ago the cry was raised that the coal supply would be exhausted in about five months or in some other very short time, but those engaged in the coal trade appear to be pretty much alive even yet; and so indeed do the members of the iron and steel trades, for I hear that there is a firm putting down a plant locally for producing steel billets at a price which will compete even with Germany or Belgium. If we in our particular

sphere each try to do all we can to the best of our ability, I think that is the most that can be expected of us.

Mr. W. B. RUBERY proposed the toast of "The Honorary Members." He observed that in Mr. Walter Somers they had an excellent President from the ranks of the honorary members, and as a result of his faithful services to the Institute, he had had three consecutive years of office. He (Mr. Rubery) was glad to find that Professor Turner was not pessimistic in his outlook on trade. He sometimes thought it was a mistake to be so pessimistic. He was one who believed that the British working man could still produce a first-class article and beat all comers, if not hounded down or worried. With reference to the question of production, he (Mr. Rubery) did not believe in a big output so much as a remunerative output. It was a frequent thing to hear people boast of their immense trade, and when asked what profit they made, to reply, "Oh, we made a loss, but look at our output!"

Mr. JAMES PROCTOR responded.

Mr. R. BUCHANAN submitted the toast of "The Past-presidents."

Mr. WALTER SOMERS responded, and said he was very much struck when he went to Scotland with the explanations of various parts of machinery given to the members by the owners and managers of the various works. He was sure that in Scotland, at any rate, there was no lack of interest displayed in the direction of putting down labour-saving apparatus. If more manufacturers had gone with the party on that occasion he believed that what was seen would have led to more labour saving appliances being put down in Staffordshire. He was pleased to hear that at last, steel was going to be made in Staffordshire at such a price as to knock the bottom out of foreign competition. There must be more combination between masters, managers, and workmen, the sort of combination which existed to a pleasing degree in Scotland. He might mention, whilst on the works improvements, that his firm would have their large press at work at Halesowen during the summer. He hoped to see ingots of some 30 or 40 tons weight manipulated by that press this year; and next year, up to 80 tons.

"The Guests" was proposed by Mr. H. SILVESTER, and responded to by Alderman G. H. DUNN and Mr. J. E. JONES.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

BALANCE SHEET,

FOR YEAR ENDING 31st DECEMBER, 1904.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Balance brought forward	121	19	11	By Expenses at Annual Meeting ...	7	4	6
„ Subscriptions	160	0	0	„ Printing and Stationery	107	6	2
„ Books and Papers Sold	24	5	0	„ Shorthand Notes	14	11	6
„ Interest on Invested Funds	3	4	8	„ Postages and Telegrams...	18	18	8
„ Balance of Excursion Account ...	2	13	2	„ Carriage and Sundry Expenses ...	6	19	6
				„ Rent...	8	0	0
				„ Secretary's Honorarium	20	0	0
					183	0	4
				Invested at 2½ per cent., £112 5 11	129	2	5
				In Treasurer's hands, £ 16 16 6			
	£312	2	9		£312	2	9

Examined with Vouchers and found correct this 18th day of April, 1905.

RICHARD ROUND,
JAMES RAYBOULD, } AUDITORS.

RULES.

REGISTERED No. 943, WORC.

1.—The Society shall be designated "The Staffordshire Iron and Steel Institute." Its registered office is in England, and is at the Institute Wolverhampton Street, Dudley, in the County of Worcester. In the event of any change in the situation of the registered office, notice of such change shall be sent within fourteen days thereafter to the Registrar, in the form prescribed by the Treasury Regulations in that behalf.

2.—This Society is subject to the provisions of the Friendly Societies' Act, 1875, except so much thereof as relates to dividing societies (section 11, sub-section 4); the certification of annuities (section 11, sub-section 5); appeals from a refusal to register a society or any amendment of the rules thereof (section 11, sub-sections 8 and 9, and section 13, sub-section 3); or from cancelling or suspension of registry (section 12, sub-section 4 and part of sub section 5); quinquennial returns and valuations (section 14, sub-section 1, *e f*); certificates of death (section 14, sub-section 2, and section 15, sub-section 9); exemption from stamp duty (section 15, sub-section 2); nomination and distribution (section 15, sub-sections 3, 4, and 5); priority on death, bankruptcy, &c., of officers (section 15, sub-section 7); copyholds (section 16, sub-section 6); loans to members (section 18); the accumulation of surplus of contributions for members' use (section 19); so much of section 22 as relates to the reference of a dispute to the chief or any other Registrar; the amalgamation, transfer of engagements, and dissolution of Friendly Societies (section 24, proviso to sub-section 8, and section 25, sub-section 1, *c*, and sub-section 7); militiamen and volunteers (section 26); the limitation of benefits (section 27); payments on the death of children (section 28); societies receiving contributions by collections (sections 30); cattle insurance and certain other societies (section 31); and the four last heads of Schedule II.

3.—The objects of the Institute are:—To promote the intellectual welfare of its members by periodical meetings for reading and discussing scientific papers on subjects connected with the Iron and Steel Trades, and such other matters as may be considered within the scope of the special authority of 3rd July, 1878 ("The Promotion of Literature, Science, and Fine Arts.") The expenses incurred in carrying out the above objects shall be provided by the subscriptions of Life and Honorary

[illegible]

[illegible]

[illegible]

11.—Any member whose subscriptons shall be two years in arrear shall be thereby disqualified, and the Council, after having given due notice, in the Form D in the Appendix, shall remove his name from the list of members, unless satisfactory reasons are given to the contrary.

OFFICERS.

12.—The officers of the Institute shall consist of a President, a Vice-president, Twenty-one Members of the Council, Three Trustees, a Treasurer, and a Secretary, who shall be elected at the annual meeting by show of hands. The President, Vice-president, Treasurer, and Secretary shall be *ex-officio* members of the Committee of Management, herein termed Council. Officers may be removed by a special general meeting.

13.—In addition to the *ex-officio* members, the Council shall consist of Twenty-one members, all of whom shall retire annually, but shall be eligible for re-election, with the exception of those who have not attended any of the Council meetings called during the year for which they have been elected.

14.—The Council shall meet as often as the business of the Institute requires; seven to form a quorum. Such meetings to be called by the Secretary, of which seven clear days' notice shall be given.

15.—The Council shall appoint from its own body two Committees, one to be called the Finance Committee, which shall advise the Council on matters relating to the receipts and expenditure of the Institute; and the other to be called the Publication Committee, which shall arrange for suitable papers to be read at the meetings of the Institute, and shall undertake the revision of all printed transactions. The Council shall provide the Secretary with a sufficient number of copies of the Rules to enable him to deliver to any person on demand a copy of such rules, on payment of a sum not exceeding One Shilling; and it shall be the duty of the Secretary to deliver such copies accordingly.

DUTIES OF OFFICERS.

16.—The President shall be chairman at all meetings at which he shall be present, and in his absence the Vice-president. In the absence of the Vice-president, the members shall elect a chairman for that meeting.

17.—The Treasurer shall hold in trust the uninvested funds of the Institute, which shall be deposited at a bank approved by the Council; he shall receive from the Secretary all amounts paid by way of subscription, contribution, or payment; and shall pay all accounts that are properly certified as correct by the President and Secretary. He shall keep proper books of account, and shall submit them once a year, or oftener if required by the Council, to the Auditors appointed, and shall

supply the Secretary with a duplicate copy of his balance sheet.

18.—The Secretary shall attend all meetings, carry on the general business and correspondence of the Institute, arrange meetings for the reading of papers and for other purposes, and keep minutes of all proceedings, which shall be authenticated by the signature of the Chairman. He shall collect all subscriptions and pay the same to the Treasurer, and shall prepare and send the Returns required by the Friendly Societies' Acts and the Treasury Regulations to be sent to the Registrar. He shall be paid an honorarium on March 25th in each year, in addition to any sums he may expend on behalf of the Institute for postages, stationery, printing, or travelling expenses.

19.—The Trustees, each of whom must be a householder, and in whose names the properties and surplus funds of the Institute shall be invested, shall continue in office during the pleasure of the Institute, and in the event of any of them dying, resigning, or being removed from office, another or others shall be elected at the next general meeting of the Institute. A copy of every resolution appointing a Trustee shall be sent to the Registrar within fourteen days after the date of the meeting at which such resolution was passed, in the form prescribed by the Treasury Regulations in that behalf.

MEETINGS.

20.—The annual meeting shall be held in April in each year.

21.—General meetings shall be held as often as business requires. The place of such meetings to be decided at the previous annual meeting.

22.—The President or the Council, in case he or they at any time think it necessary, or the President, on the requisition of six members, may convene a special general meeting of the Institute, for the consideration of any subject requiring the immediate attention of members. The business of such meeting shall be confined to the special subject named in the notice convening the same.

23.—All members shall have at least six clear days' notice of, and be entitled to attend, each meeting of the Institute, and to receive copies of the Institute's publications gratuitously.

24.—No alterations of the Rules shall be made except at a general meeting, and four weeks notice in writing must be given to the Secretary of any proposed alterations. No amendment of Rules is valid until registered.

AUDITORS.

25.—The accounts, together with a general statement of the same and all necessary vouchers, up to the 31st December then last, shall be submitted once in every year to two auditors, appointed by the members

at the general meeting preceding each annual meeting, who shall lay before every such meeting a balance sheet (which either may or may not be identical with the annual return, but must not be in contradiction to the same), showing the receipts and expenditure, funds and effects of the Institute, together with a statement of the affairs of the Institute since the last meeting, and of their then condition. Such Auditors shall have access to all the books and accounts of the Institute, and shall examine every balance sheet and annual return of the receipts and expenditure, funds and effects of the Institute, and shall verify the same with the accounts and vouchers relating thereto, and shall either sign the same as found by them to be correct, duly vouched, and in accordance with law; or shall specially report to the meeting of the Society before which the same is laid in what respects they find it incorrect, unvouched, or not in accordance with law; and the balance sheet or report shall be published in the *Proceedings* of the Institute.

COMMUNICATIONS OF MEMBERS AND OTHERS.

26.—All communications shall be submitted to the Council, and after their approval, shall be read at the general meetings. All communications shall be the property of the Institute, and shall be published only in the *Proceedings* of the Institute, or by the authority of the Council.

PROPERTY OF THE INSTITUTE.

27.—All books, communications, drawings, and the like shall be accessible to all the members. The Council shall have power to deposit the same in such place or places as may be considered most convenient for the members.

INVESTMENT OF FUNDS.

28.—As much of the funds of the Institute as may not be wanted for immediate use, or to meet the usual accruing liabilities, shall, with the consent of the Council, or a majority of the members of the Institute, present at a general meeting, be invested by the Trustees in such of the following ways as the Council or General meeting shall direct, namely, in the Post Office Savings Bank, in the Public Funds, or with the Commissioners for the reduction of the National Debt, upon Government or real securities in Great Britian, or upon the security of any County, Borough, or other rates authorised to be levied or mortgaged by Act of Parliament.

ANNUAL AND OTHER RETURNS.

29.—It shall be the duty of the Committee of Management to keep a copy of the last annual balance sheet of the Society for the time being, together with the Report of the Auditors, if any, always hung up in a conspicuous place at the registered office of the Society—Friendly Societies Act, 1875, s. 14 (1 *i.*)

30.—The books and accounts of the Society shall be open to the inspection of any member or person having an interest in the funds of the Society at all reasonable times, at the registered office of the Society or at any place where the same are kept, and it shall be the duty of the Secretary to produce them for inspection accordingly.

31.—Every year before the 1st June, the Committee of Management shall cause the Secretary to send to the Registrar the annual return, in the form prescribed by the Chief Registrar of Friendly Societies, required by the Friendly Societies Act, 1875, of the receipts and expenditure, funds and effects of the Society, and of the number of members of the same, up to the 31st December then last inclusively, as audited and laid before a general meeting, showing separately the expenditure in respect of the several objects of the Society, together with a copy of the Auditors' report, if any.

32.—Such return shall state whether the audit has been conducted by a public auditor appointed under the Friendly Societies Act, 1875, and by whom, and if such audit has been conducted by any persons other than a public auditor, shall state the name, address, and calling or profession of each of such persons, and the manner in which, and the authority under which, they were respectively appointed.—Friendly Societies Act, 1875, s. 14 (1 *d.*)

33.—It shall be the duty of the Committee of Management to provide the Secretary with a sufficient number of copies of the annual return or of some balance sheet, or other document duly audited, containing the same particulars as in the annual return as to the receipts and expenditure, funds and effects of the Society, for supplying gratuitously every member or person interested in the funds of the Society, on his application, with a copy of the last annual return of the Society, or of such balance sheet or other document as aforesaid, for the time being, and it shall be the duty of the Secretary to supply such gratuitous copies on application accordingly.—Friendly Societies Act, 1875, s. 14 (1 *h.*)

DISSOLUTION.

34.—The Society may at any time be dissolved by the consent of three-fourths of the members, including honorary members, if any, testified by their signatures to some instrument of dissolution in the form provided by the Treasury Regulations in that behalf.

DISPUTES.

35.—If any dispute shall arise between a member, or person claiming through a member, or under the Rules of the Society, and the Society, or any officer thereof, it shall be referred to justices pursuant to the Friendly Societies Act, 1875, s. 22 (*c.*)

APPENDIX.

FORM A.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

Mr.
of
being of full age and desirous of becoming a member of The Staffordshire Iron and Steel Institute, we, the undersigned, from our personal knowledge, do hereby recommend him for election.

His qualifications are

Witness our hands this day of 190

} Names of two members.

If elected a member of The Staffordshire Iron and Steel Institute, I, the undersigned, do hereby engage to ratify my election by signing the Form of Agreement (C) and paying the Entrance Fee and Annual Subscription in conformity with the Rules.

Witness my hand this day of 190

FORM B.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

To

SIR,

I beg to inform you that on the
you were elected a member of The Staffordshire Iron and Steel Institute, but in conformity with the Rules, your election cannot be confirmed until the accompanying form be returned with your signature, together with your Entrance Fee and first Annual Subscription. (Amount, £ s. d.)

If this amount be not received in one month from this date, your election will become void.

I am, Sir,

Yours truly,

Secretary.

day of 19

FORM C.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

I, the undersigned, being elected a member of the Staffordshire Iron and Steel Institute, do hereby agree that I will be governed by the rules of the Institute, and that I will advance its interests as far as may be in my power. Provided that if I signify in writing to the Secretary that I am desirous of withdrawing my name therefrom, I shall (after paying all arrears which may be due by me at that period) be free from this obligation.

Witness my hand this day 19

Member's Signature.

FORM D.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

DEAR SIR,

I am directed by the Council to inform you that your subscription to the Institute, amounting to
is still in arrear, and that if the same be not paid to me on or before the day of your name will be removed from the lists of the Institute.

Yours faithfully,

Secretary.

OFFICERS FOR SESSION 1906-1907.

President:

WILLIAM SOMERS.

Vice-President:

ROBERT BUCHANAN.

Trustees:

ALFRED COOKSON, MOSES MILLARD, WILLIAM B. RUBERY.

Treasurer:

JAMES PIPER.

Council:

THOMAS ASHTON	G. H. HEAD
JOHN BATE	WALTER JONES
W. BROOKS	R LYTHGOE
JOSEPH BROWN	WALTER MACFARLANE
ALFRED COOKSON	FRANK EAST NURSE
JAMES DONECHAY	W B RUBERY
RD. EDWARDS	HARRY SILVESTER
DAVID EVANS	LEYSHON D. THOMAS
W. J. FOSTER	H. B. TOY
J. W. HALL	THOMAS TURNER
W. H. B. HATTON	

Secretary:

WILLIAM H. CARDER, Tividale Road, Burnt Tree, Tipton.

LIST OF PRESIDENTS.

[illegible]	[illegible] HENRY FISHER
[illegible]	[illegible] GEORGE [illegible] WRIGHT
[illegible]	[illegible] HENRY ABBY
[illegible]	[illegible] ALEXR. [illegible] TURNER
[illegible]	[illegible] HERBERT [illegible] ILKINGTON
[illegible]	[illegible] HERBERT [illegible] ILKINGTON
[illegible]	[illegible] THOMAS TURNER
[illegible]	[illegible] JAMES ROBERTS
[illegible]	[illegible] THOMAS ASHTON
[illegible]	[illegible] WILLIAM H. RUBERY
[illegible]	[illegible] WILLIAM THOMANS
[illegible]	[illegible] JNO. V. HALL
[illegible]	[illegible] H. LE NEVE FOSTER
[illegible]	[illegible] HARRY SILVESTER
[illegible]	1900 LEYSHON D. THOMAS
[illegible]	1901 WALTER SOMERS
[illegible]	1902 WALTER SOMERS
[illegible]	1903 WALTER SOMERS
[illegible]	1904 HARRY B. TOY
[illegible]	1905 WALTER JONES

LIST OF MEMBERS.

(CORRECTED TO 30TH JUNE, 1906).

HONORARY MEMBERS.

Adams, George, and Sons, Limited,
Mars Ironworks, Wolverhampton

Akrill, C., and Co., Limited,
Gold's Green Foundry, West Bromwich.

Baldwins, Limited,
Wilden, near Stourport.

Bantock, Thos., and Co.
Wolverhampton.

Bayliss, Jones. and Bayliss, Limited,
Victoria Works, Wolverhampton

Bradley, Jno., and Co,
Stourbridge.

Bromford Iron Co., Limited,
West Bromwich.

Buckley, Samuel.
St. Paul s Square, Birmingham.

Bunch, B., and Sons,
Staffordshire Ironworks, Walsall

Chatwin, Thomas,
Market Foundry, Tipton

Cochrane and Co.,
Woodside Ironworks, Dudley.

Dudley, Earl of,
Priory Offices, Dudley.

Gilchrist, P. C., F.R.S. (Life),
Frognal Bank, Finchley Road, Hampstead, London, N.W.

Grazebrook, M. and W.,
Netherton Ironworks, near Dudley.

Guest, Josiah, and Sons,
Victoria Foundry, West Bromwich.

Harris Brothers,
Brierley Hill.

Harrison, G. K., Ltd.,
Lye Fire-clay and Brick Works, Stourbridge,

Hickman, A., Limited,
Spring Vale Furnaces, near Wolverhampton.

Hingley, N., and Sons, Limited,
Netherton Ironworks, Dudley.

Hutchinson, W.,
7, Park Road West, Wolverhampton

Ironmonger, C. W.,
Great Brick-kiln Street, Wolverhampton.

Jones, Walter,
Holly Mount, Red Hill, Stourbridge.

Keay, E C. and J., Limited,
Prince's Chambers, Corporation Street, Birmingham.

Kirk, Henry,
19, Marsh Side, Workington.

Knowles, J.,
Wolseley House, Wednesbury.

Lees, Maurice,
Parkbridge Ironworks, Ashton under-Lyne.

Lilleshall Co., Ltd.,
Priors Lee Hall, near Shifnal.

Lloyd, F. H., and Co., Limited,
James Bridge Steel Works, near Wednesbury.

Lones, Vernon, and Holden, Limited,
Smethwick, near Birmingham.

McBean, Alexander, J.P.,
Lichfield-street, Wolverhampton.

Macpherson, Geo. J.P.,
Green Royde, Pedmore, Stourbridge.

Parkes, E., and Co.,
Atlas Ironworks, West Bromwich.

Patent Shaft and Axletree Co., Limited,
Wednesbury.

Pearson, J. H.,
Netherton Furnaces, near Dudley.

Perry, T. and Son, Limited,
Highfields Works, Bilston.

Procter, James,
Wrockwardine Villa, Oakengates, Salop.

Roberts and Cooper,
Brierley-Hill.

Russell, Jno. and Co., Limited,
Cyclops Ironworks, Walsall.

Shropshire Iron Co., Limited,
Hadley, near Wellington, Salop.

Siemens, F.,
10, Queen Anne's Gate, Westminster, S W.

Simpson, F. F,
Park Lane Ironworks, Oldbury.

Somers, Walter, J.P.,
Belle Vue, Halesowen, Birmingham.

Spencer, John, Limited,
Globe Tube Works, Wednesbury.

Stewarts and Lloyds, Ltd.,
Coombs Wood Tube Works, Halesowen, near Birmingham.

Summers, John, and Sons, Limited,
Globe Ironworks, Stalybridge.

Tangyes, Limited,
Cornwall Works, Birmingham.

Taylor and Farley,
Summit Foundry, West Bromwich.

Webb, H. A.,
Church-street Chambers, Stourbridge.

Westley, W.,
Shaw Road, Dudley.

ORDINARY MEMBERS.

Addenbrooke, Geo. L.,
53, Victoria-street, Westminster, London, S.W.

Allen, Job,
49, Grange Road, West Bromwich.

Arrowsmith, Joseph,
Station Road, Brockmoor, Brierley-Hill.

Ashton, T.,
"Branksome," Netherton, near Dudley.

Astle, Joseph,
Stourbridge Road, Halesowen, near Birmingham.

Aston, G. B.,
Rangemere, Goldthorn Hill, Wolverhampton.

Aston, Joseph,
176, Kynaston Place, High-street, Bolton.

Attwood, W.,
21, Merry Hill, Quarry Bank, Brierley-Hill.

Bagnall, F. W.,
Ivy Dene, Birmingham Road, Halesowen, near Birmingham.

Baker, Alexr. J.,
Grassington, Green-street, Smethwick.

Baker, Wm. T.,
196, Wednesbury Road, Walsall.

Banks, A. R.,
33, High-street, West Bromwich.

Barklam, Geo.,
Bracmar, Dudley Port, Tipton.

Barnsley, J. W.,
Netherton, near Dudley.

Bate, Jno.,
Bamford House, Haden Hill, Old Hill, Staffs.

Belcher, Joseph,
67, Beeches Road, West Bromwich.

Bennett, Frank A.,
Cambridge House, Hallam-street, West Bromwich.

Bennett, Thomas,
Mead End, Halesowen, Birmingham.

Betts, Thomas,
88, Jervoise-street, West Bromwich.

Birkbeck, Arthur,
Grosvenor Chambers, Wolverhampton.

Birkinshaw, W. G. K.,
Reliance Works, Derry-street, Wolverhampton.

Blake, Harry B.,
7, Lea Road, Wolverhampton.

Bloomer, Clifford E.,
Shenstonville, Halesowen, Birmingham.

Blunt, Edward,
Pensnett Road, Holly Hall, near Dudley.

Booth, G. E.,
9, Platts Crescent, Amblecote, Stourbridge.

Booth, Horatio,
The Limes, Dennis Park, Stourbridge.

Brooks, W.,
Montrose, Scott's Green, Dudley.

Broughton, W. K.,
3, Nelson Road, Dudley.

Brown, Joseph,
Sandyfields, Sedgley, near Dudley.

Bryce, D.,
Pennett, Dudley

Buchanan, Robert,
5, Thornhill Road, Handsworth, near Birmingham.

Bunch, Herbert,
Linley, Lichfield Road, Walsall.

Burford, H.,
18, Duncombe-street, Wollaston, Stourbridge.

Burton, Wingfield,
Albert House, Bilston.

Bushell, C. E.,
Albert Sheet Ironworks, West Bromwich.

Carder, W. H.,
Tividale Road, Burnt Tree, Tipton.

Carrington, Geo.,
Ironston Villa, Sheephridge, Chesterfield.

Challingsworth, W. H.,
Carlton Villas, Cavendish Road, Edgbaston, Birmingham.

Chambers, Geo. K.,
56, Hagley Road, Birmingham.

Chapman, Busby,
70, Ralton Park Road, Birmingham.

Chasser, Geo.,
15, Heath-street, Stourbridge.

Colley, J.,
Hillingdon, Dover-street, Bilston.

Cookson, A.,
Coalbournbrook, Stourbridge.

Crofts, F. J.,
Bloomfield House, Tipton.

Crump, E. B.,
46, Tunnel street, Cosely, Bilston.

Danks, W. H.,
133, Bridge street, Wednesbury.

Darby, Jno. W.,
39, Parliament street, Bury, Lancashire

Davis, Charles H.,
25, Broad street, New York City, U.S.A.

Davies, David,
11, High street, West Bromwich.

Devitt, Michael,
Netherton Furnaces, Dudley.

Donechay, James,
Tipton Green House, Tipton

Dorsett, William,
Brookdale, Stourport.

Downing, Isaac,
Church Road, Blackheath, Birmingham.

Drabble, Jas. H.,
4, Oswald Gardens, Scotstounhill, Glasgow.

Dudley, B. J.,
Bromsgrove-street, Halesowen, near Birmingham.

Dudley, T. H.,
Lloyds' Proving House, Cradley Heath, Staffs.

Edwards, A. E. A.,
63, South Road, Smethwick.

Edwards, C. E.,
Collis street, Amblecote, Stourbridge.

Edwards, R.,
The Laurels, 16, Mellish Road, Walsall.

Evans, D.,
Plant street, Old Hill, near Dudley.

Evers, H Lancelot,
34, King Edward Road, Coventry.

Farnworth, E.,
Broadlands, Goldthorn Hill, Wolverhampton.

Fieldhouse, J.,
94, St. Paul's Road, West Smethwick.

Fisher, G. H.,
6, Mount Pleasant, Bilston.

Foster, Humphrey, F.
The Woodlands, West Bromwich.

Foster, W. J.,
Northfield, Darlaston Road, Walsall.

Freeman, David,
36, New Cross, Heath Town, Wolverhampton.

Gale, Walter,
16, Trinity Road, West Bromwich.

Gibbs, Geo. H.,
Station Road, Brockmoor, Brierley Hill.

Gough, William H.,
South Yorkshire Ironworks, Sheffield.

Hadley, C. A.,
Stoneleigh, Frederick Road, Gravelly Hill, Birmingham.

Hadley, J. G.,
Waterfall Lane, Blackheath, Birmingham.

Hall, J. W.,
Athenæum Chambers, 71, Temple Row, Birmingham.

Hammond, H. A.,
Cordley, Dudley Road, West Bromwich.

Hammond, Herbert,
Elmwood, Worcester Road, Lower Hagley, near Stourbridge.

Hannah, J. C.,
Groveland Road Works, Tipton.

Harley, John,
Waterloo Road, North, Wolverhampton.

Harper, Armah,
Springfield, Spring-street, Stockton-on-Tees.

Harper, Emmanuel,
Cox's Lane, Old Hill, near Dudley.

Harris, E.,
310, Stony Lane, Smethwick.

orn, T.,
South View, Bent-street, Brierley-Hill.

, W. Howard B.,
Saltwells House, near Brierley-Hill.

ns, W. R.,
The Crown Foundry, Dudley Port, Tipton.

George H.,
Jesmond Dene, Castle Road, Tipton.

len, John,
Lawrence Lane, Old Hill, Staffs.

an, W. W.,
Station Road, Brockmoor, Brierley-Hill.

Charles H.,
60, Reid-street, Crewe.

George,
116, Londonderry Road, Smethwick.

/m.,
Midland Coal, Coke, and Iron Company, Ltd., Newcastle, Staffs.

iss, Thomas,
King's Hill Villa, Wednesbury.

e, T. E.,
173, Blackburn Road, Darwen.

ton, Edward,
106, Saltergate, Chesterfield

, Edward O ,
Clifton Villa, Level-street, Brierley-Hill.

Clifford,
The Furlongs, Sedgley, near Dudley.

W. H.,
16, Bagnall-street, West Bromwich.

ı, O. F.,
The University, Birmingham.

ı, W. J. (Life),
4, Cliff Gardens, Frodingham.

Armstrong, [illegible]

Leather Cloth Factory, Bilston-street, Bromley-Hill.

Ashe, Harold,

71, Victoria Road, Smethwick.

Cross, [illegible]

Carrara Ironworks, Port Clarence, Middlesbro'-on-Tees.

Cross, R. J.

The Poplars, Whitwell, Mansfield.

Keeling, John

Victoria House, Netherton, near Dudley.

Kendrick, W.

65, Great Bridge-street, West Bromwich.

King, Wm.

Fentham, Greenfield Road, Harborne, Birmingham.

Knowles, Thomas R.

Old Park Terrace, Wednesbury.

Lashford, Wm.,

Cobham Road, Halesowen, near Birmingham.

Lee, William,

39, Lawrence Lane, Old Hill, Staffs.

Legge, A. H.

Oldswinford, near Stourbridge.

Lenox, L. Gordon, J.P.,

Neachridge Works, Pontypridd.

Lester, Edgar C.,

District Ironworks, Walsall.

Lester, Isaac E.,

91, Westminster Road, Handsworth, Birmingham.

Lewis, Fredk.,

The Vicarage, Upper Gornal, near Dudley.

Lewis, Geo.,

14, Arundale Road, Wolverhampton.

Lewis, John,

Coldwell Foundry, Kidderminster.

Lindop, Wm ,
149, Tividale Road, Burnt Tree, Tipton.

Lycett, J. A.,
Castle Hill, Wolverley, near Kidderminster.

Lythgoe, Richard,
Lorne Villa Bank street. Brierley-Hill.

McBean, Archibald D. G.,
Tyninghame, Tettenhall, Wolverhampton.

Macfarlane, Walter,
Kelvin, Wednesbury.

McSwiney, A ,
14, Lansdowne Road, Handsworth, Birmingham.

Mantle, Joseph,
Limes Road, Tettenhall, Staffs

Matty, W. H.,
Langley, near Birmingham.

Meiklejohn, J. Robert,
14, Frost Street, Ettingshall, Wolverhampton.

Mercer, R. G.,
270, Edward Road, Edgbaston, Birmingham.

Meese, Daniel,
"*Lonsdale,*" *Toll End Road, Ocker Hill, Tipton.*

Mensforth, H ,
61, Urmston Lane, Stretford, Manchester.

Meredith, S.,
Tividale Road, Tipton.

Micklewright, William,
Osborne House, Wood Green, Wednesbury.

Millard, Frederick J.,
24, Blakenall Lane, Ledmore, Walsall.

Millard, M.,
Oakleigh, Humber Road, Wolverhampton.

Mills, Frederick,
Ebbw Vale Steel, Iron, and Coal Company, Limited, Ebbw Vale, R.S.O., Mon.

Millward, E.,

Beecher House, Cradley Heath, Staffs.

Millward, Thomas.

The Woodlands, Button Oak, near Dudley.

Molineaux, W.,

107, Oxford Street, Bilston.

Moore, Algernon W.,

Carlton Chambers, 31, Lichfield Street, Wolverhampton.

Moore, Frank,

Lupal Lodge, Quinton, Birmingham.

Moore, William,

Spring Vale House, Ettingshall, Wolverhampton.

Moore, W. G.,

3, Wellington Road, Birmingham.

Moulder, Wm.,

230, Bearwood Road, Smethwick.

Mountford, Percy,

5, Hagley Road, Stourbridge.

Muras, Robert,

83, Darlington-street, Wolverhampton.

Musgrove, W.,

Hatherton Furnaces, Bloxwich, Walsall.

Nicklin, J. B.,

Summer Hill House, South Road, Smethwick.

Nock, Joshua,

17, Wanderers' Avenue, Wolverhampton.

Northwood, Joshua,

109, Oxford-street, Bilston.

Nurse, Frank East,

Eastcroft, Grange Road, West Bromwich.

Oliphant, W. A.,

Haywood Forge, Halesowen, Birmingham.

ons, W J,
95, Beeches Road, West Bromwich.

e, Fred. W.,
32, Wellington Road, Bilston.

ett, W. W.,
Wollaston, Stourbridge.

es, W. J.,
Haywood House, Halesowen, near Birmingham.

y, Wm,
28, Slaney Road, Bescot, Walsall.

ridge, H. E.,
9, Grange Road, West Bromwich.

rson, John (Life),
Belle Isle Place, Workington.

on, J.,
19, Sycamore Road, Handsworth, Birmingham.

ngton, H. (Life), M.Inst.C.E.,
Sheepbridge Ironworks, Chesterfield.

r, Harold,
The Hawthorns, Collis-street, Amblecote.

r, J.,
The Hawthorns, Collis-street, Amblecote.

t, Ernest,
33, Collis-street, Amblecote, Stourbridge.

t, W. H,
287, Tividale, Tipton.

A.,
Mount Pleasant, Bilston.

y, Isaac,
The Limes, Wilden, near Stourport.

Pugh, Jno. E.,
Belmont House, James Street, Masbrough, Rotherham.

Raby, E. J.,
140, South Road, Erdington.

Rathbone, C. H.,
49, Allen Road, Wolverhampton.

Raybould, James,
Adelaide-street, Brierley-Hill.

Reed, Edward, A.,
Gate Villa, Sedgley, Staffs.

Riddle, W. G. L.,
Elmdon, Cadbury Road, Moseley, Birmingham.

Robbins, James A.,
19, Sedgley Road, Tipton.

Robertson, C. J.,
7, Jesson-street, West Bromwich.

Robinson, Philip,
Emerald Villa, Holly Lane, Smethwick, Birmingham.

Rose, T. Lawrence,
Wellington Road, Pilston.

Round, R,
Woodcote, Amblecote, Stourbridge.

Rubery, W. B.,
Hill Crest, Woolsetton, Dudley

Rudge, Harry,
Rumbow, Halesowen, Birmingham.

Rushworth, David,
Clay Cross Ironworks, near Chesterfield.

Salter, Thomas E.,
Princes End, Tipton.

Screen, Ernest Arthur,
17, Horseley Heath, Tipton.

Screen, William T.,
Fair View, Horseley Heath, Tipton.

Shedden, Duncan J.,
Dixon's Green, Dudley.

Shenton, Jas. W.,
35, Bromford Lane, West Bromwich.

Silvester, H., B.Sc., F.C.S.,
78, Holyhead Road, Handsworth.

Simons, W.,
Coatbridge Villa, Basford, Stoke-on-Trent.

Siviter, Stewart S.,
Fern Villa, Grammar School Lane, Halesowen, near Birmingham.

Skinn, Benjamin,
421, Stourbridge Road, Holly Hall, Dudley.

Slater, Samuel K.,
Atlas Brass Foundry, Hurst Hill, near Bilston.

Smith, A. J.,
13, Auckland Road, Smethwick.

Smith, J. Kent,
32, Hough Green, Chester.

Smith, T. H.,
Princes End Foundry, Tipton.

Smith, W. S.,
Neachells Road, Wednesfield, Wolverhampton.

Somers, Frank,
Haywood Forge, Halesowen, Birmingham.

Somers, Seth S.,
High Harcourt, Old Hill, Staffs.

Somers, William,
Haywood Forge, Halesowen, Birmingham.

Stephens, Geo.,
Brasshouse Lane, Smethwick.

Steward, H. B.,
Rose Hill House, Coseley, Bilston.

Sutherland, Duncan G.,
34, Thynne Street, West Bromwich.

Tarbolton, C. E.,
3, Greenfield Crescent, Edgbaston, Birmingham.

Thomas, E. F.,
Birchills Ironworks, Walsall.

Thomas, F. G.,
Birchills Ironworks, Walsall.

Thomas, L. D.,
Bromley House, Pensnett, near Dudley.

Thompson, E. S.,
Bradley Boiler Works, Bilston.

Thompson, S. J.,
Ettingshall Boiler Works, Wolverhampton.

Tilley, J. P.,
120, Wellington Road, Dudley.

Timmins, W.,
28-29, Hall-street, Dudley.

Toy, Harry B.,
41, Nicholls-street, West Bromwich.

Treglown, C. H.,
3, Soho Avenue, Handsworth, Birmingham.

Tucker, A. E., F.I.C.,
Norwich Union Chambers, Birmingham.

Turley, T.,
Glenleigh, Woodsetton, near Dudley.

Turley, Thos,
35, Stafford-street, Wednesbury.

Turner, Professor T., M.Sc., A.R.S.M., F.I.C.,
The University, Birmingham.

Venables, W. H.,
Farringford, Vicarage Road, Smethwick.

Waldron, H. Westwood,
11, Bescot Road, Bescot, Walsall.

Wall, Charles H.,
Redclyffe, Halesowen, Birmingham.

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Haden Hill, Old Hill, Staffordshire.

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Westley, W., Jun.,
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Westwood, Samuel,
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Whitehouse, Ernest J.,
77, Dudley Road, Tipton.

Whitehouse, G. H.,
Gilwern, Phœnix Street, West Bromwich

Whitehouse, H. B., junr.,
Priorfield Furnaces, Bilston.

Whitmore, Samuel.
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Whittaker, J. H.,
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Willcox, Thomas.
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Williams, Albert.
Alban House, Pinfold Street, Darlaston.

Williams, G.,
Millbrow House, Parkbridge, Ashton-under-Lyne.

Winwood, Thomas,

Castle Road, Tipton.

Wones, Will. K.,

Greenhill, Wombourn, Wolverhampton.

Woodhouse, Hy,

Kelvin, North Street, Dudley.

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Worton, Fred.,

The Orchard, Round Oak, Brierley-Hill.

Wright, Edward,

Mostyn, Villa, Lower Hill street, Stourbridge.

Wynn, William,

Beacon View, Wood Green, Wednesbury.

Yates, Charles R.,

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Yeomans, C.,

Talbot-street, Brierley Hill.

Yeomans, W.,

Hawes Hill, Rowley Regis, near Birmingham,

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"Iron and Steel Trades Journal,"
"Science and Art of Mining,"
"Page's Weekly."

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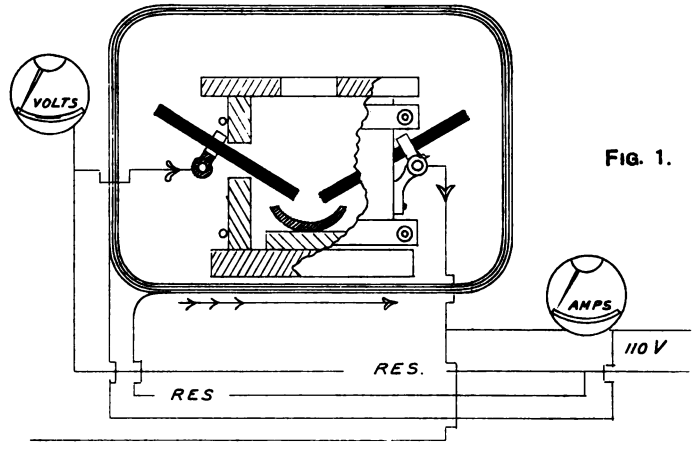

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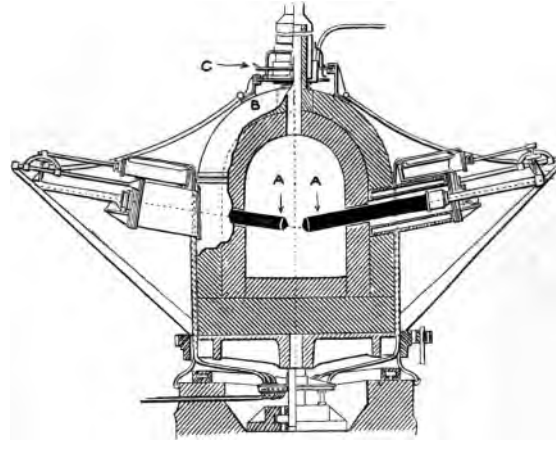
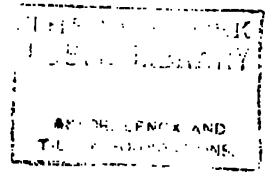


The Stassano Furnace, latest form (longitudinal section.)

Fig. 2.



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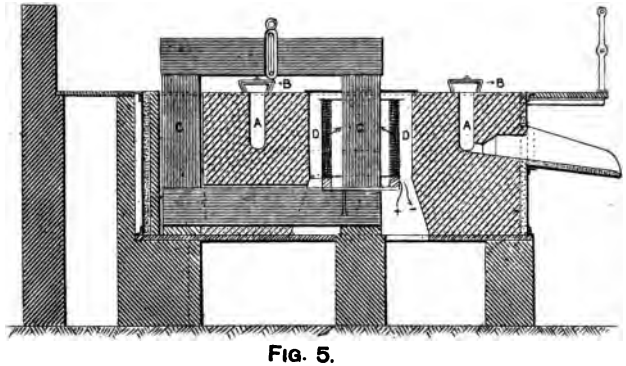

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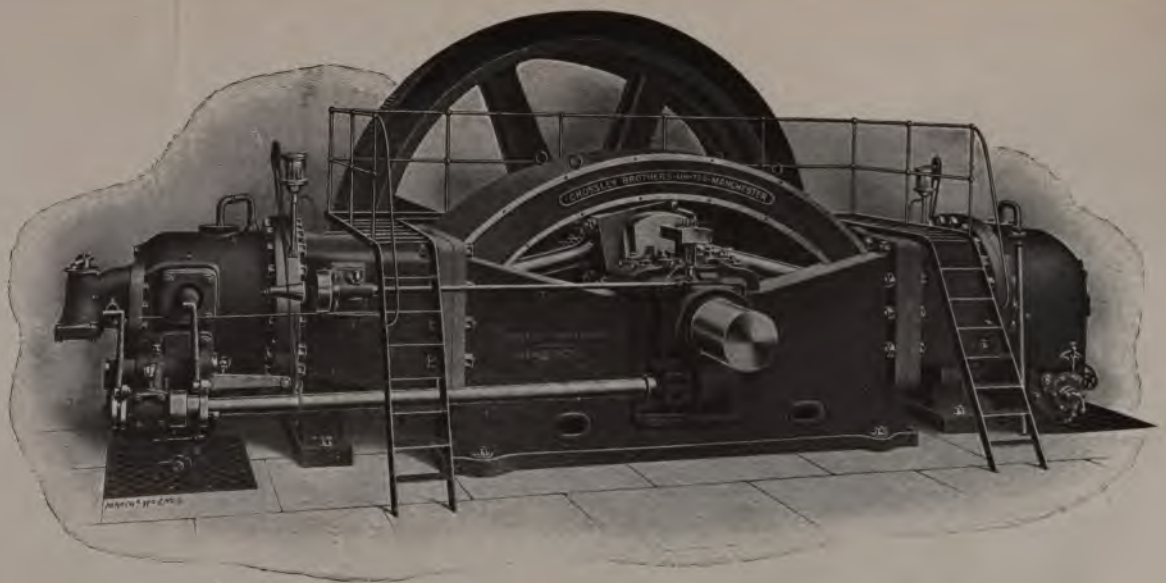

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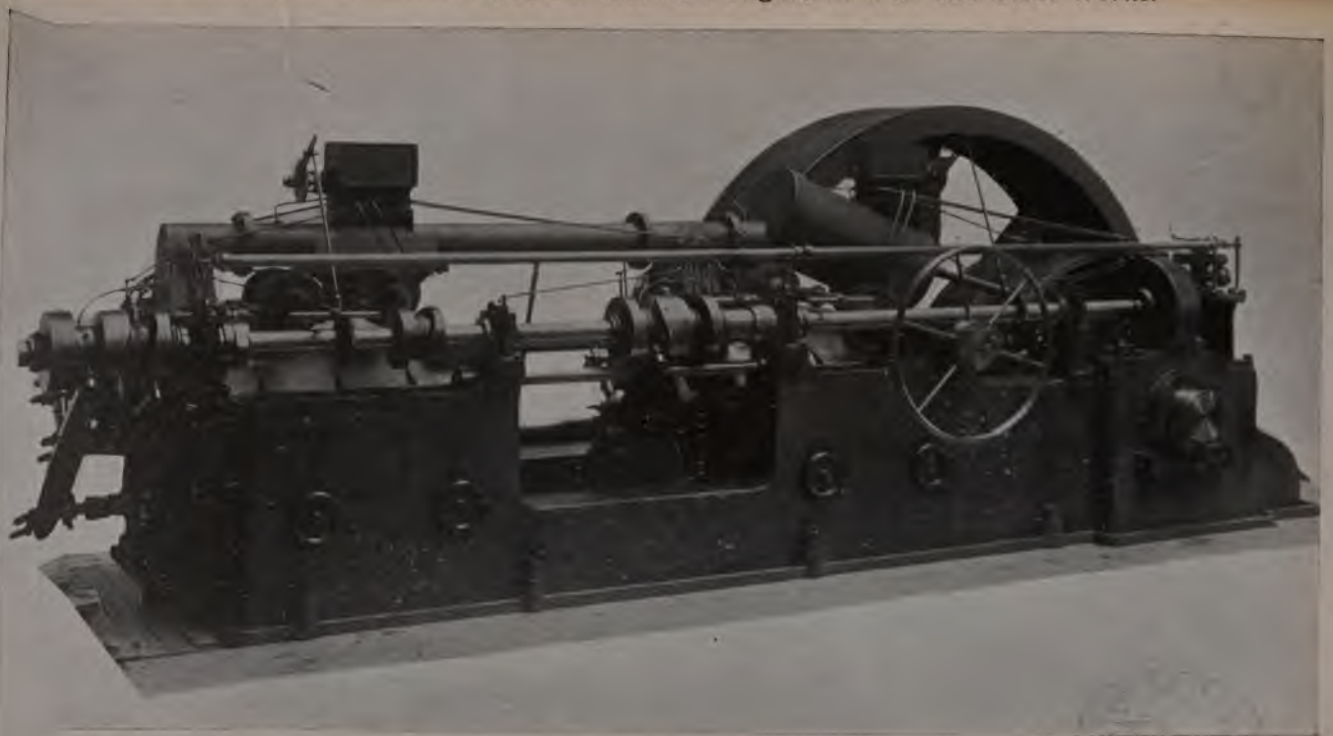

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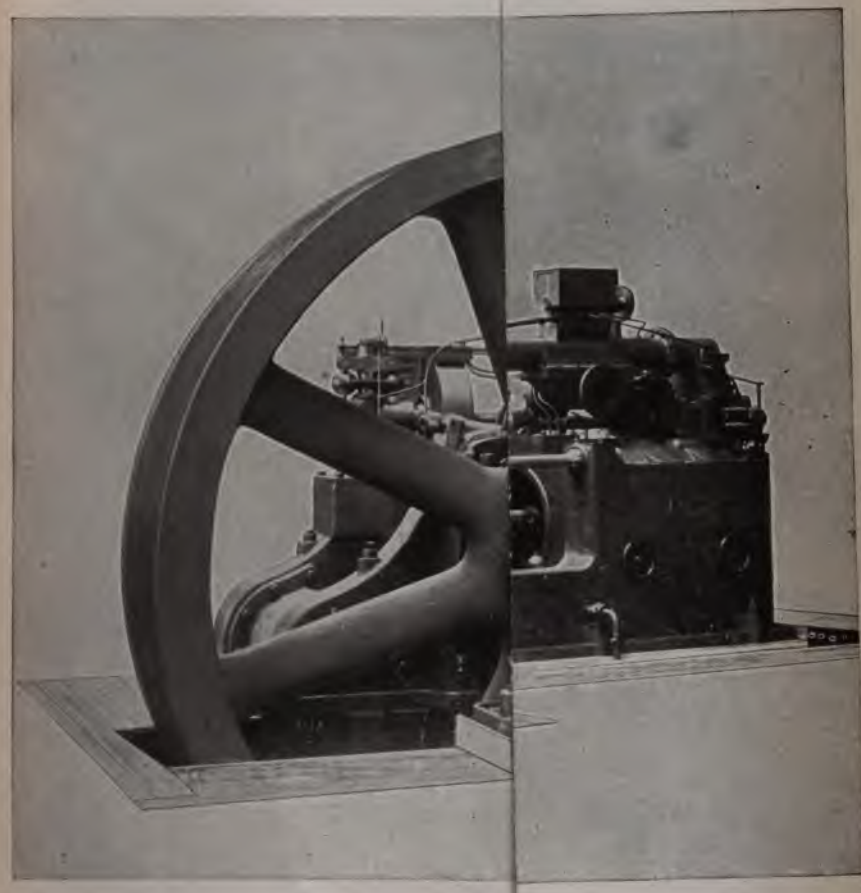

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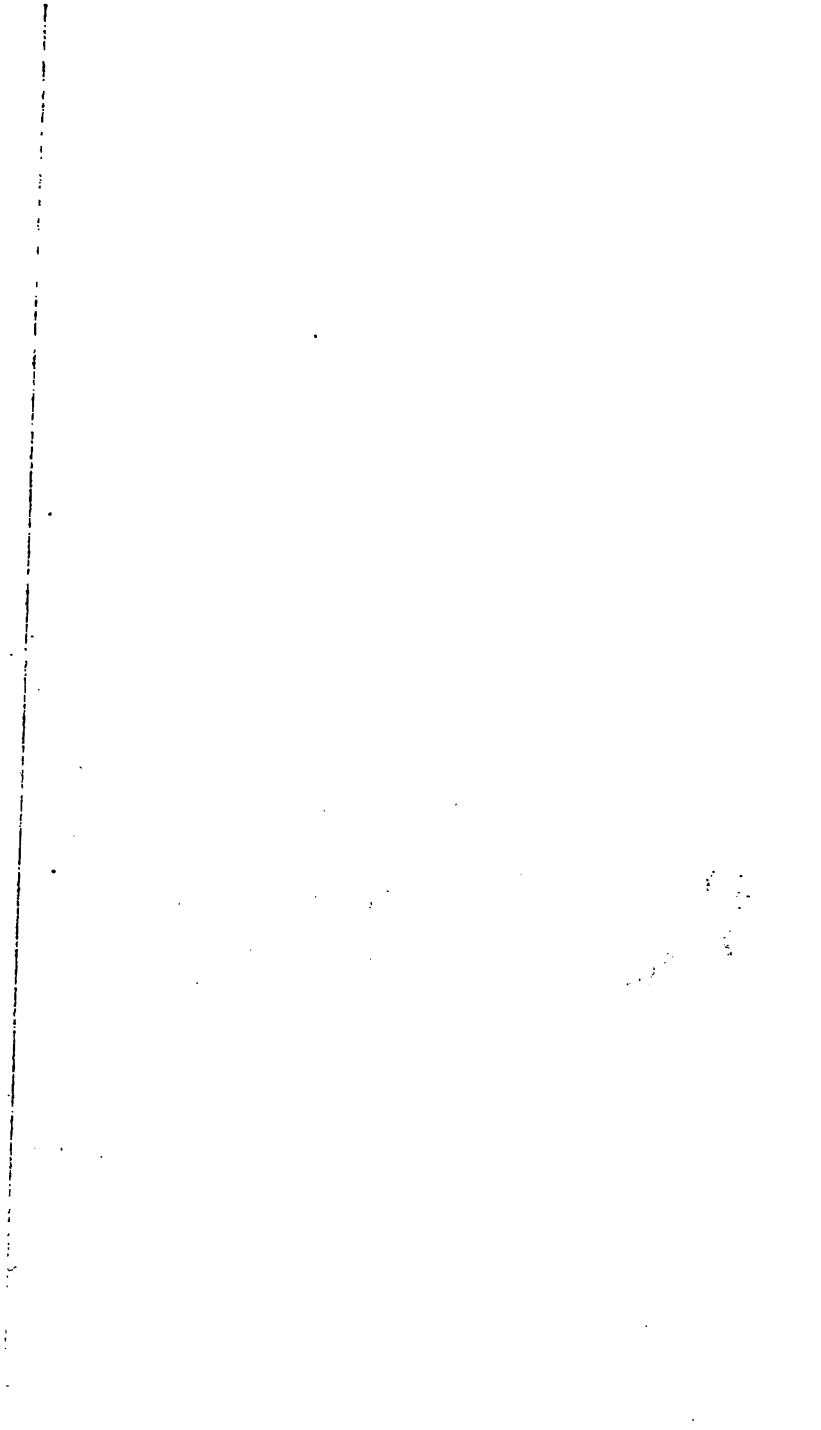

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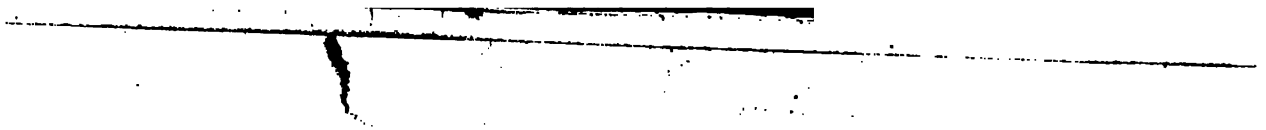

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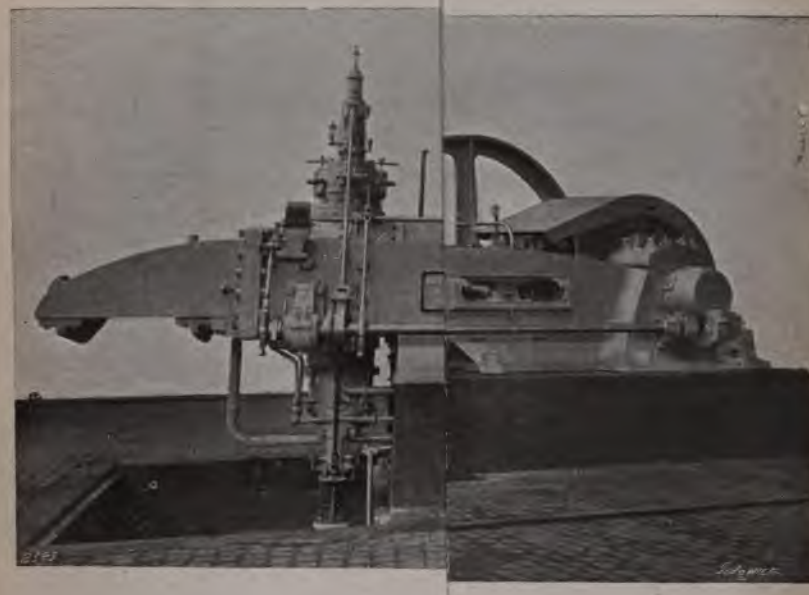

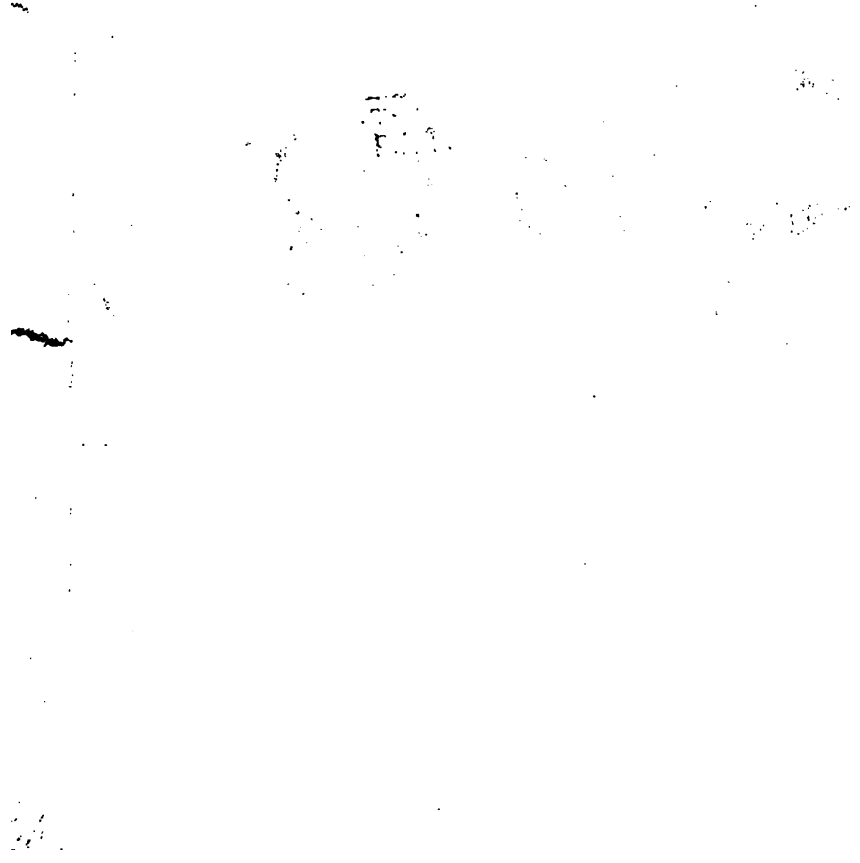

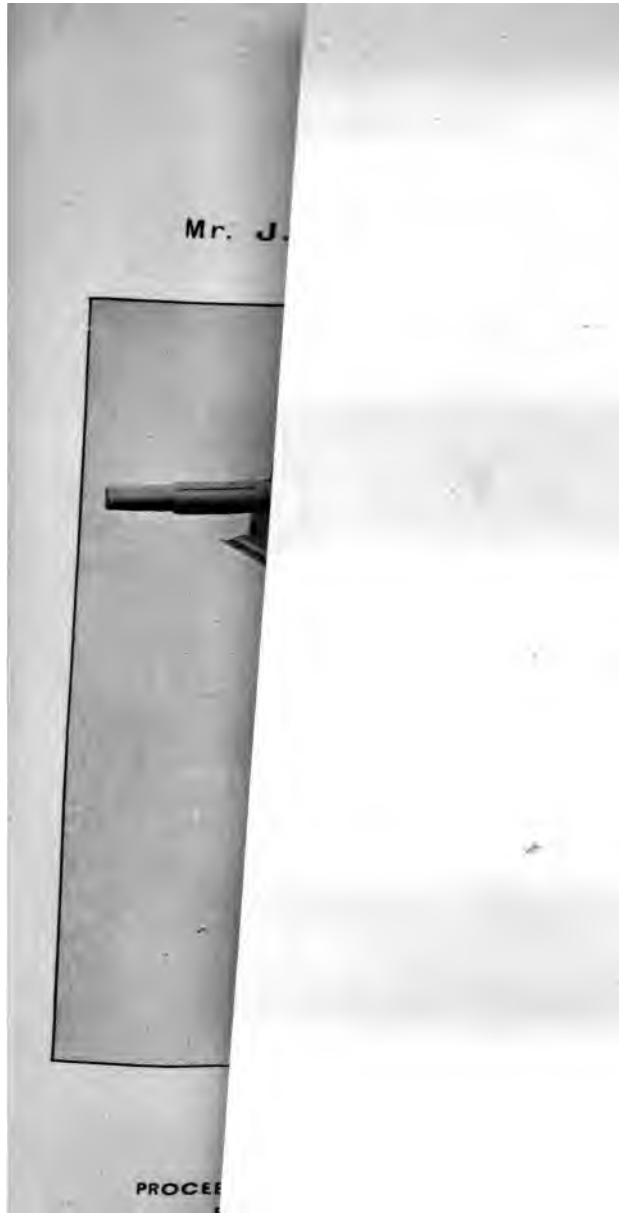
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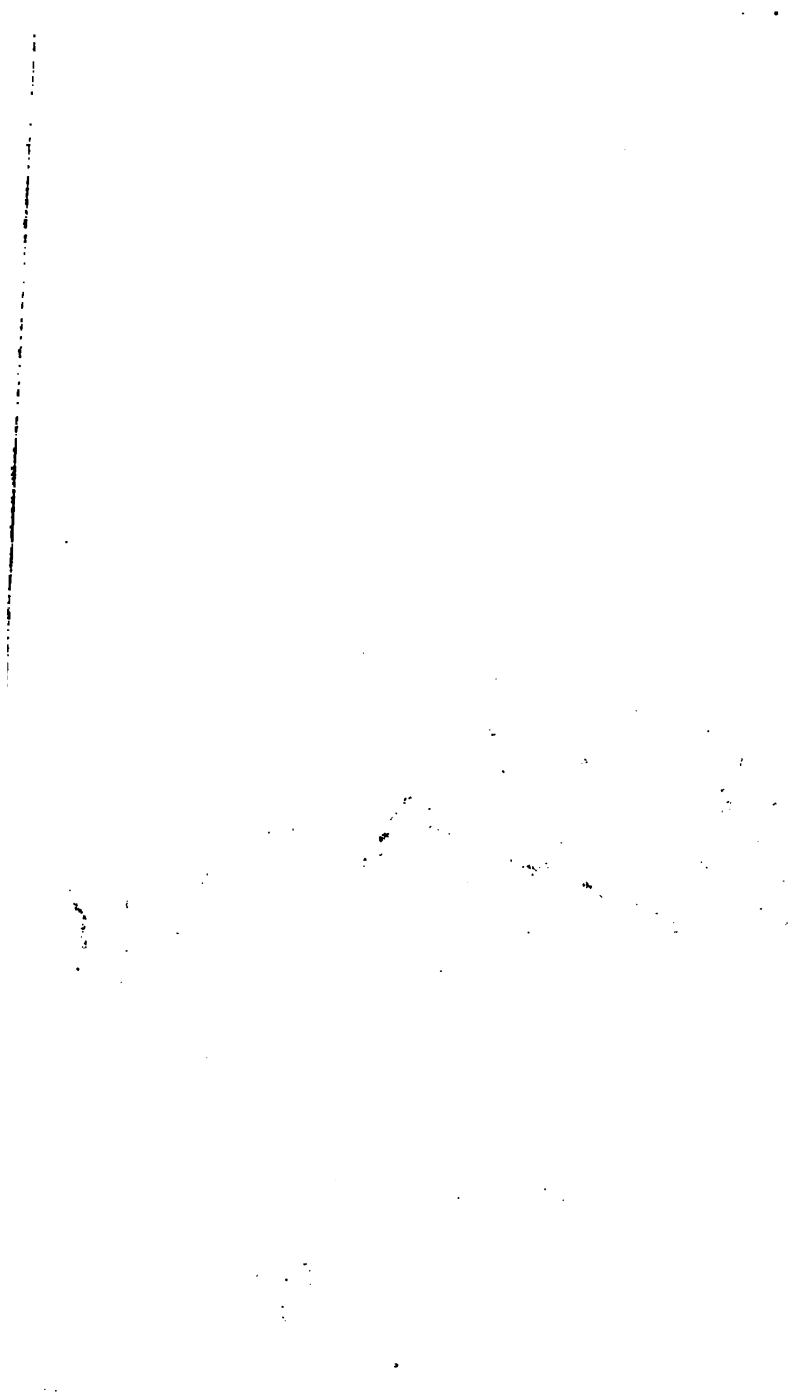

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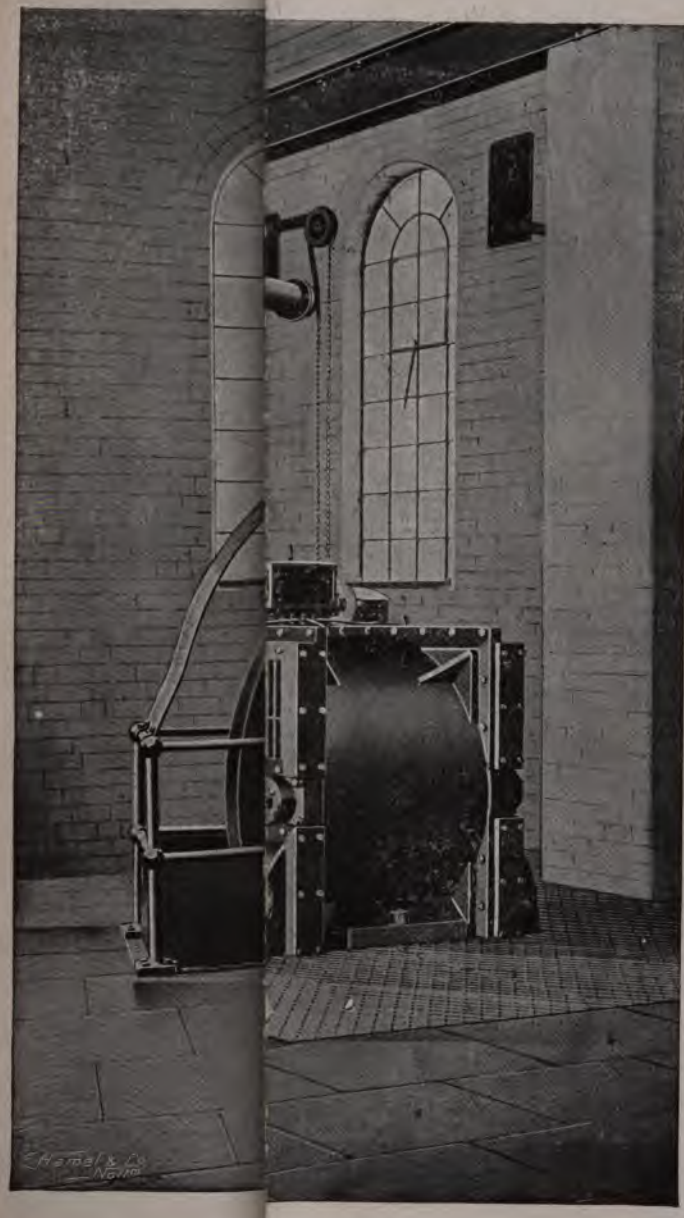

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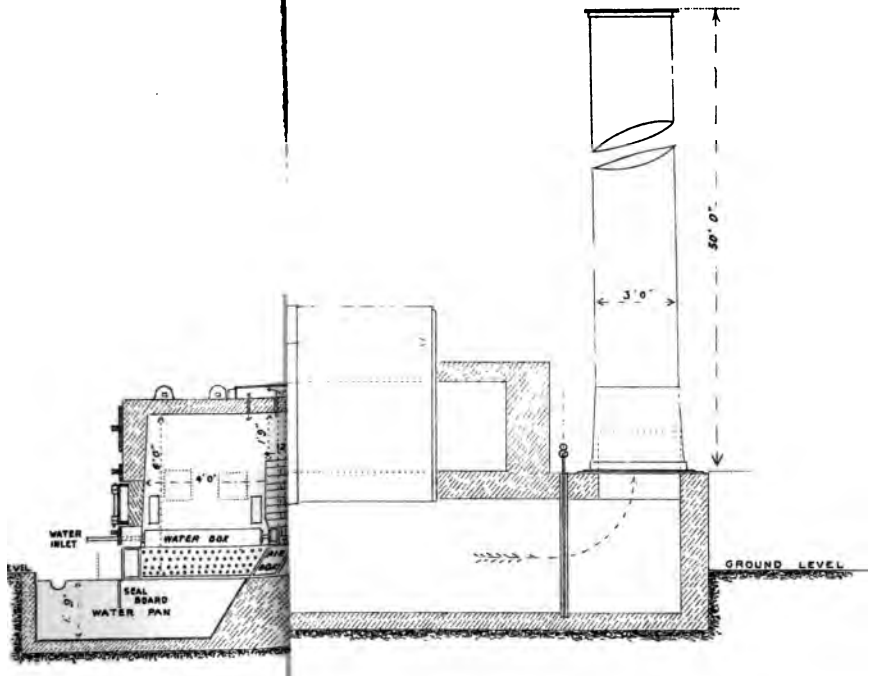

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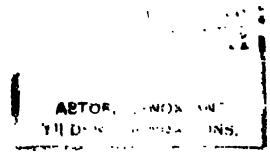
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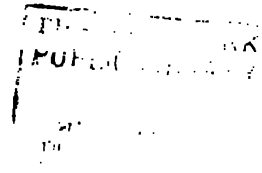

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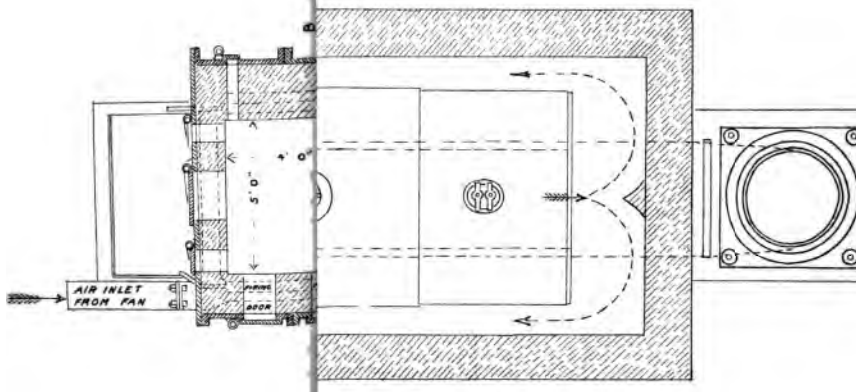

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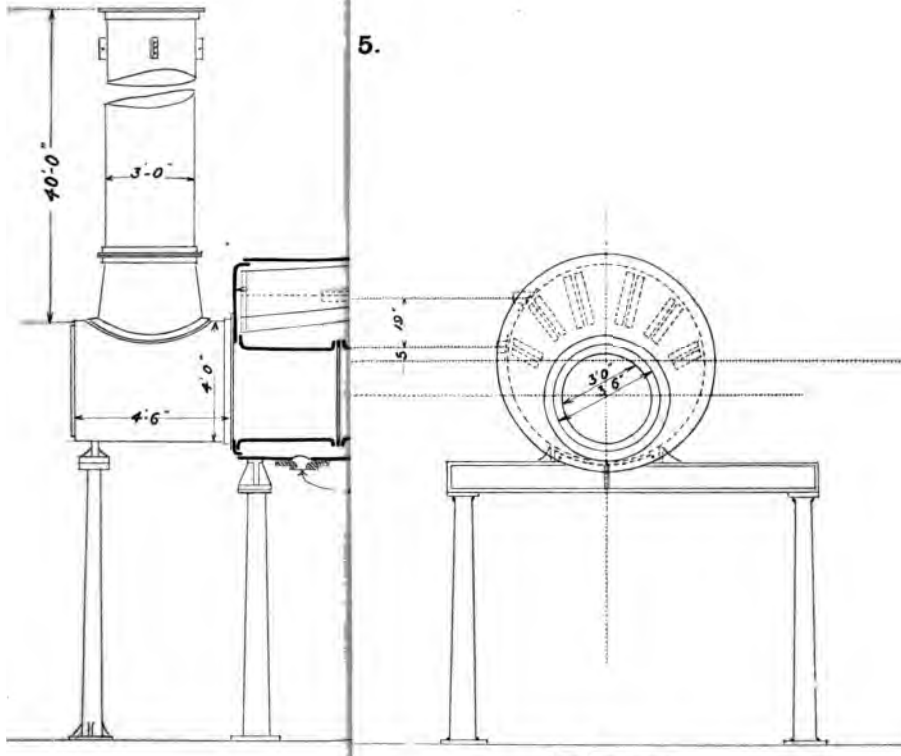

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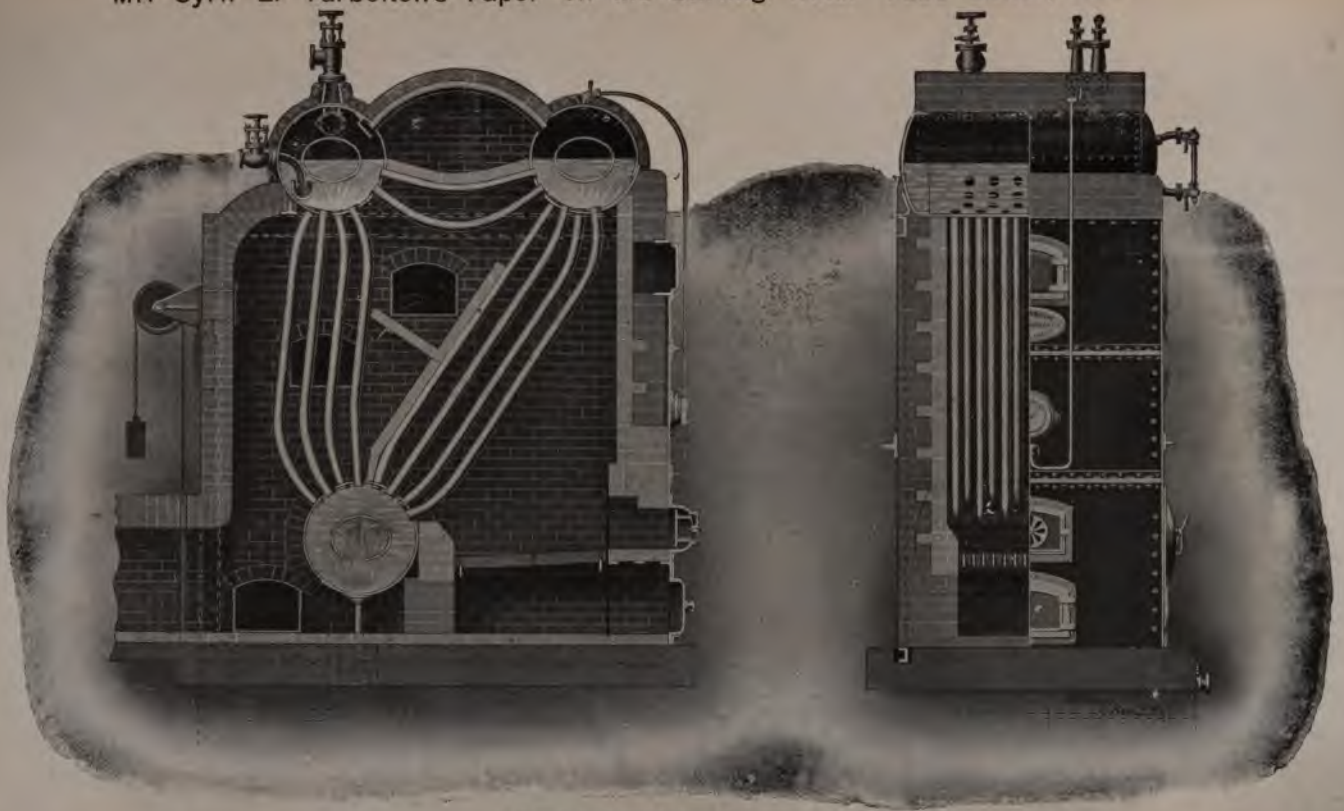

Stirling Boiler (U Type).

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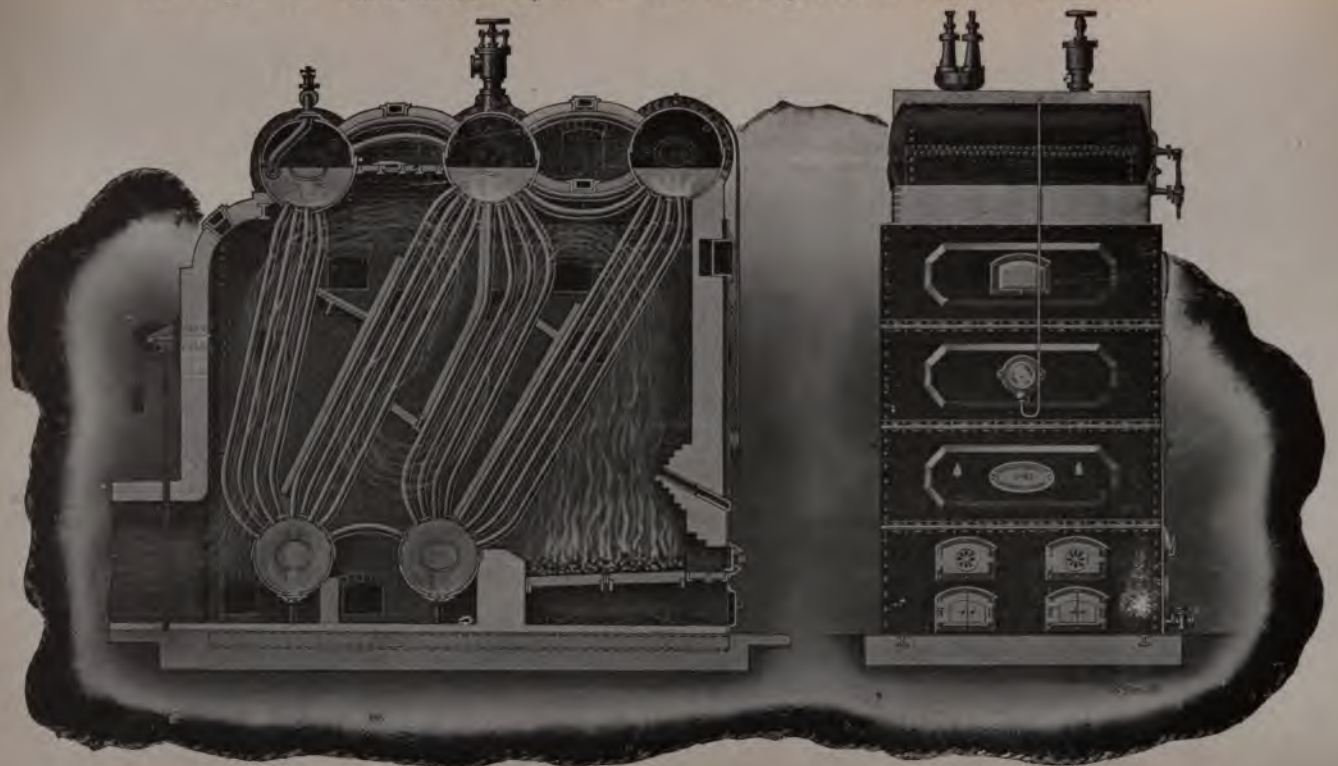

Standard Stirling Boiler (W Type).

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FIG. 1.—Swedish Grey Iron (F^LM) × 60V, * unetched, shows graphite. The clear ground mass is seen on etching to consist almost entirely of pearlite.

FIG. 2.—Hematite (Distington), No. 1 Bessemer × 60V. Picric Acid. Shows large graphite flakes surrounded by ferrite. The large dark areas are pearlite.

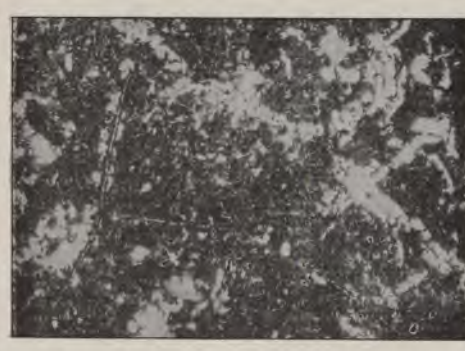


FIG. 3.—Hematite (Distington), No. 2 Bessemer × 90V. Picric *Acid.* The dark ground mass consists largely of pearlite.

* Magnified 60 diameters under vertical illumination.

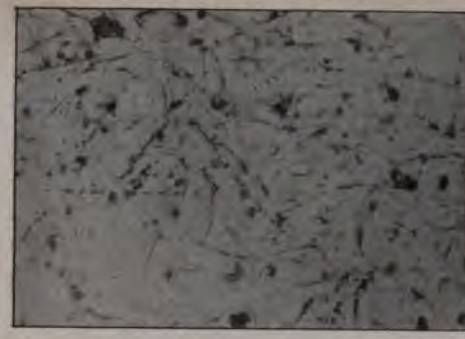


FIG 4.—Hematite (Distington), No. 3 Forge × 60V. Unetched.

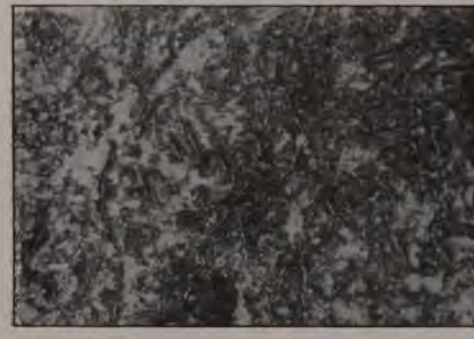
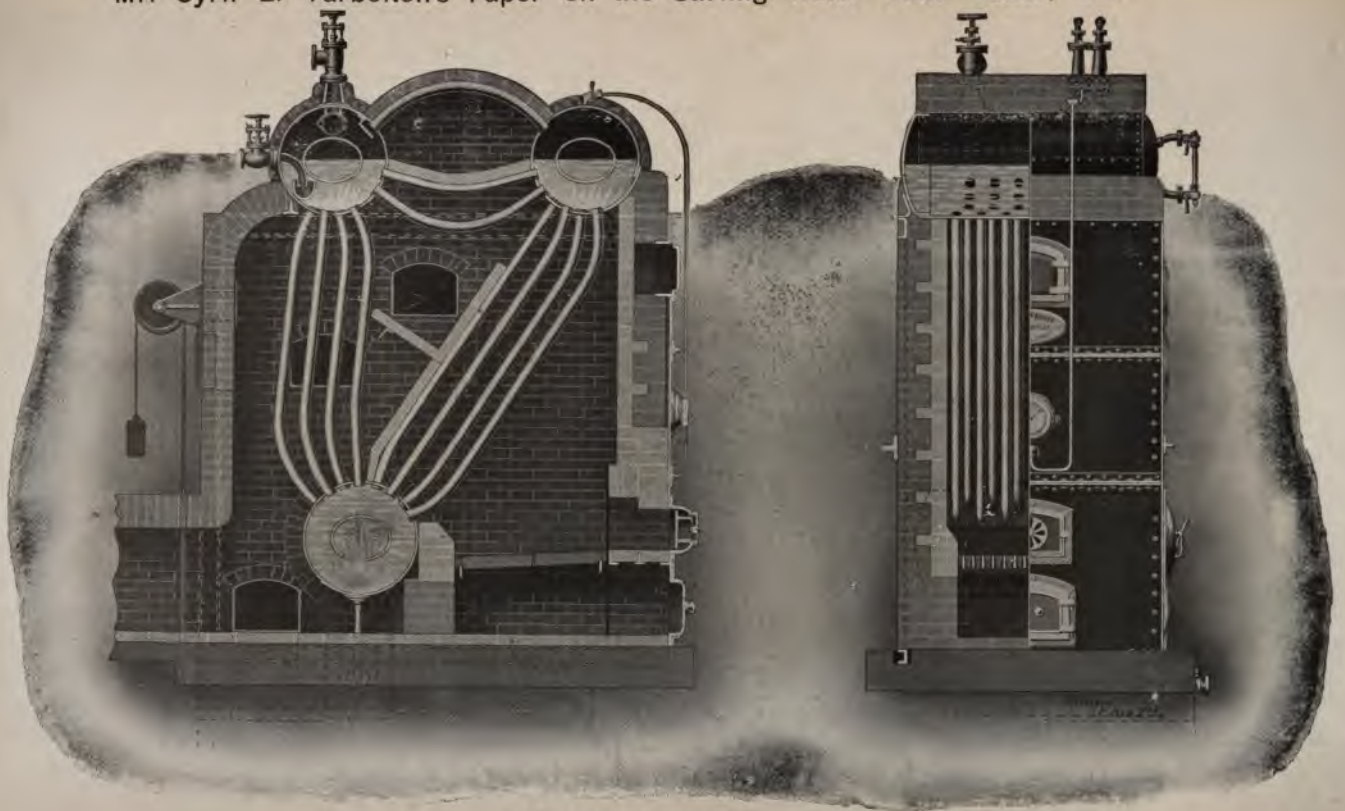


FIG.. 5.— ditto ditto Picric Acid.

FIG. 6.—Hematite (Distington), No. 4 × 90V. Picric Acid.



Stirling Boiler (U Type).

FIG. 10.—Hematite (Distington), White × 90V. Picric Acid. Consists only of cementite (white) and pearlite (dark).

FIG. 11.—Mine No. 3 Iron (Tipton Green) × 60V. Picric Acid Shows graphite (black) surrounded by ferrite (white), and enclosing phosphide eutectic. A small amount of pearlite is present forming the thickened dark boundaries of the phosphide eutectic.

FIG. 12.—Mine No. 6 Iron (Tipton Green) × 60V. Picric Acid. The light areas are phosphide eutectic and the dark parts consist of pearlite with graphite imbedded in it.

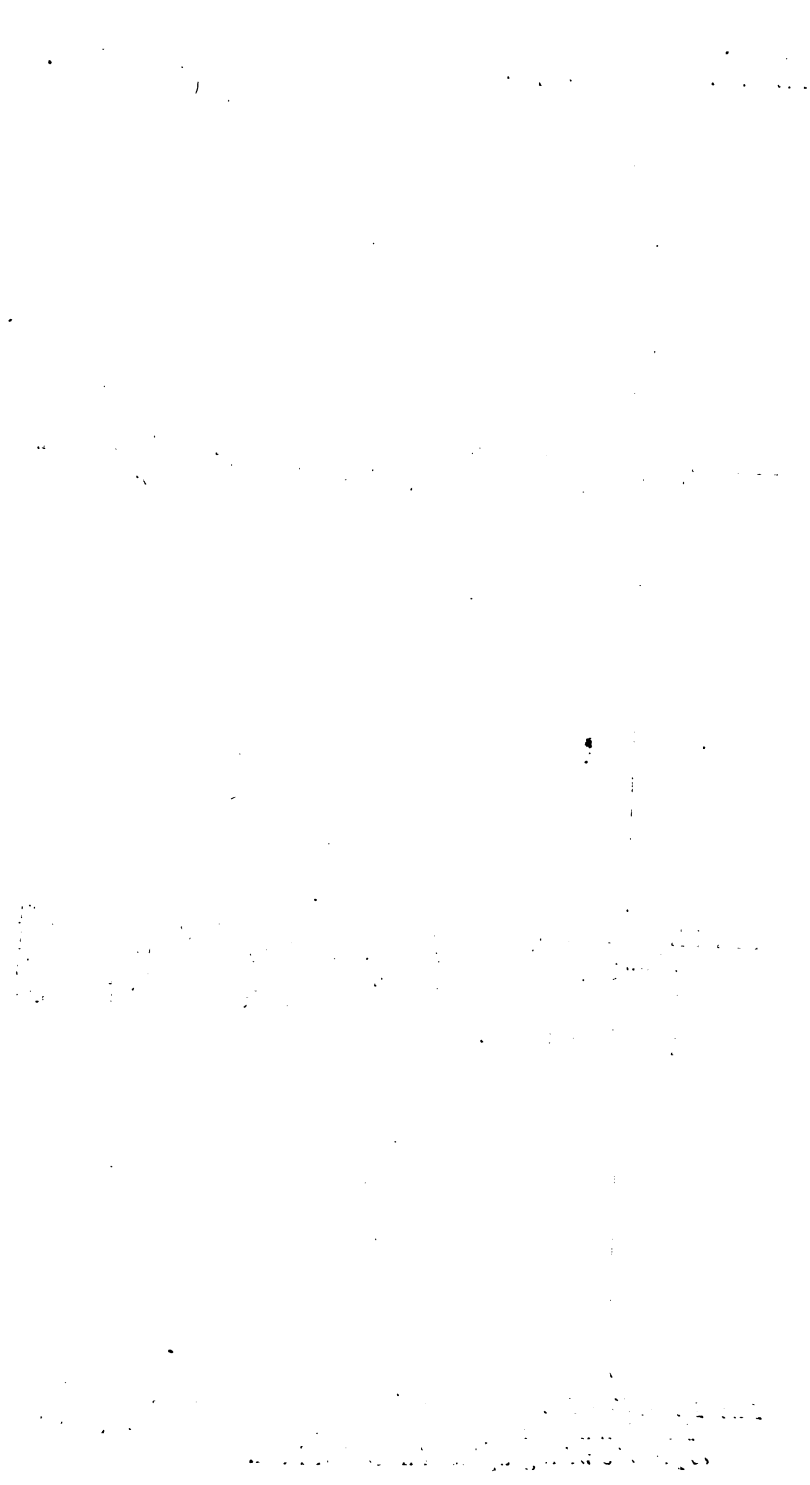


FIG. 13.—Derbyshire (Sheepbridge) No. 1 × 60V. Unetched. Coarse graphite is seen. The phosphide eutectic stands in relief.

FIG. 14.—Derbyshire (Sheepbridge) No. 1 × 90V. Picric Acid. Shows graphite, ferrite, and phosphide eutectic.

FIG. 15.—Derbyshire (Sheepbridge) No. 3 × 60V. Picric Acid. *Shows graphite, ferrite, and phosphide eutectic.*

FIG. 16.—Northampton (Islip) No 2 × 90V HNO_3. Shows large flakes of graphite. The ferrite is here somewhat stained and so not clearly distinguished from the phosphide eutectic (the mottled areas).

FIG 17.—Northampton (Islip) Glazed × 90V HNO_3. Shows small graphite, ferrite, and phosphide eutectic.

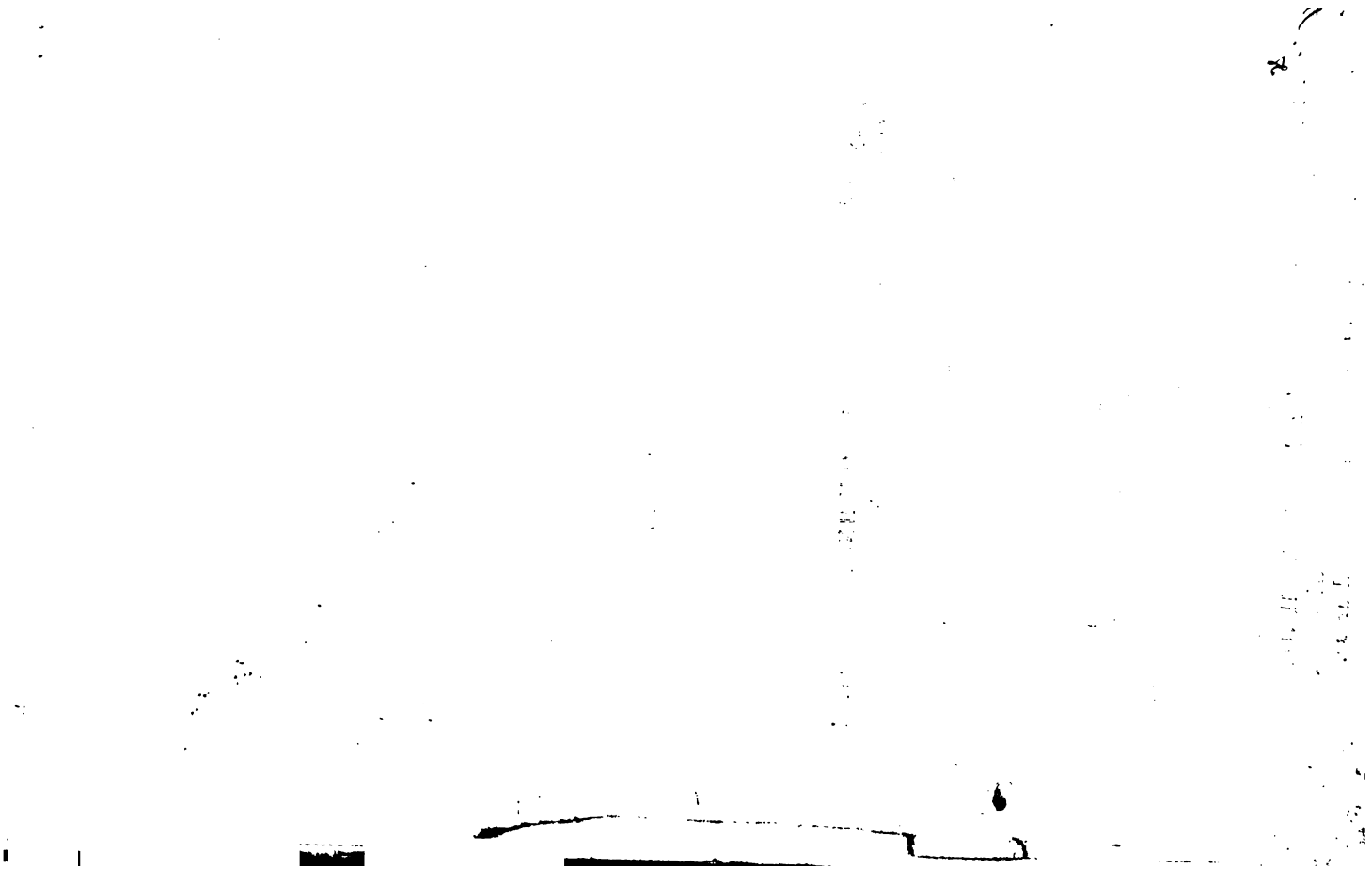



FIG. 18.—Northampton (Islip) Glazed × 300V HNO_3. Sh graphite, ferrite (the fine lines are boundaries of cryst grains and the phosphide eutectic, the banded area).